

EPA REGION 4: PLANTS 7 AND 8

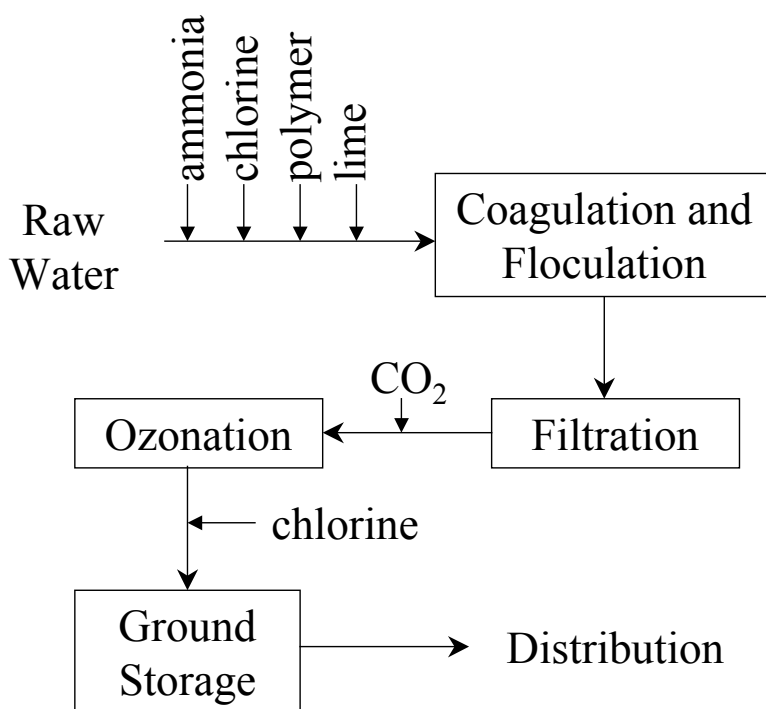
Plant Operations and Sampling

On December 11, 2000, March 12, 2001, September 24, 2001, and January 14-16, 2002, plants 7 and 8 (in EPA Region 4) were sampled.

Plant 7 is an ozone plant (Figure 1). The raw water was first treated with chloramines. The water was then lime-softened and filtered. The filtered water was ozonated. The ozonated water was chlorinated, stored, and distributed.

Figure 1

Plant 7 Schematic



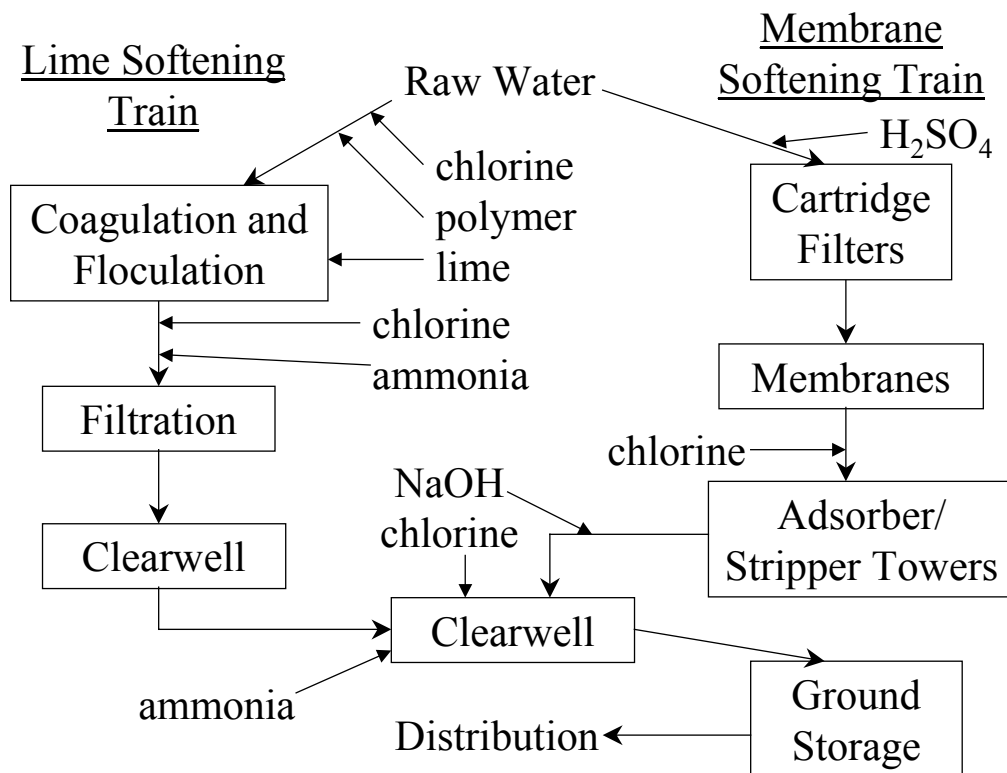
Plant 8 is a membrane plant (Figure 2). This plant consisted of two facilities operating simultaneously and parallel to one another; a portion of the water was treated with membranes:

- In the lime softening portion of the plant, the raw water was treated with chlorine. The water was then lime-softened. The softened water was chloraminated, filtered, and stored.
- In the membrane-softening portion of the plant, the pH of the raw water was adjusted with sulfuric acid. The acidified water was filtered and treated with membranes (TFC[®]-S polyamide, Koch Membrane Systems; softening, low pressure for brackish water treatment membrane elements). The membrane-treated water was chlorinated and passed through an adsorber and stripper towers. The pH of the water was adjusted with sodium hydroxide and mixed with the lime-softened water.

The combined treated waters were chloraminated, stored, and distributed.

Figure 2

Plant 8 Schematic



Plant 7 was sampled at the following locations:

- (1) raw water
- (2) settled water
- (3) filter effluent
- (4) effluent of the ozone contactor
- (5) the plant effluent

In addition, plant effluent was collected and simulated distribution system (SDS) testing was conducted (a 24-hr holding time was typically used [27-hr in January 2002]). Furthermore, the distribution system was sampled at a location that receives water from plant 7 and from another treatment plant.

Plant 8 was sampled at the following locations:

- (1) raw water
- Lime Softening
- (2) settled water
 - (3) filter effluent
- Membrane Softening
- (4) membrane effluent
 - (5) effluent of the stripper towers
- Combined Treated Waters

(6) the plant effluent

In addition, plant effluent at plant 8 was collected and SDS testing was conducted (a 24-hr holding time was typically used [22.5 h in September 2001]). Furthermore, the distribution system of plant 8 was sampled at one location.

On the day of sampling, information was collected on the operations at each plant (Tables 1-2).

Table 1. Operational information at plant 7

Parameter	12/11/00	3/12/01	9/24/01	1/14/02
Plant flow (mgd)	8.7	9.0	9.6	13.6
Total chlorine dose at plant influent (mg/L as Cl ₂)	13	10	5	5.3
Chlorine dose at influent pipe or raw standpipe (mg/L as Cl ₂)	3.0	7.0	2	2
Chlorine dose at treatment unit collector ring or basin effluent (mg/L as Cl ₂)	7.0	3.0	3	3.3
Ammonia dose at plant influent (mg/L as NH ₃ -N)	1.1	1.1	0.94	1.3
Lime dosage (mg/L)	219	225	230	243
Polymer dosage (mg/L)	0.2	0.2	0.2	0.2
CO ₂ dosage (mg/L)	8.3	4.0	10	3.6
Ozone dose (mg/L)	6.4	5.0	4	7.4
Hydraulic retention time in ozone contactor (min)	25	20	30	20
CT achieved from ozonation (mg/L-min)	NA ^a	NA	NA	0.37
Chlorine dose at ozone contactor eff. (mg/L as Cl ₂)	3.1	3.0	6.0	6.7

^aNA = Not available

Table 2. Operational information at plant 8

Parameter	12/11/00	3/12/01	9/24/01	1/16/02
Overall plant flow (mgd)	11.05	11.41	10.1	11.64
Plant flow for lime softening (mgd)	4.5	3.0	3.3	3.00
Plant flow for membrane softening (mgd)	6.55	8.41	6.8	8.64
Lime Softening				
Chlorine dose at lime softening inf. (mg/L as Cl ₂)	6.0	6.0	8.0	8
Lime dosage (mg/L)	205	225	215	225
Polymer dosage (mg/L)	0.05	0.05	0.025	0.025
Chlorine dose at filter influent (mg/L as Cl ₂)	12	12	12	12
Ammonia dose at filter influent (mg/L as NH ₃ -N)	1.0	1.0	1.0	1
Membrane Softening				
H ₂ SO ₄ dose at membrane softening inf. (mg/L)	180	180	134	182
Operating pressure (psi)	118	118	118	118
Chlorine dose at membrane effluent (mg/L as Cl ₂)	2.6	2.6	2.6	1.8
NaOH dose at stripper tower effluent (mg/L)	16.6	62	16	26
Chlorine dose at stripper tower eff. (mg/L as Cl ₂)	7.1	7.1	7.5	6.5
Combined Treated Waters				
Ammonia dose at plant effluent (mg/L as NH ₃ -N)	1.0	1.0	1.0	NA

Water Quality

On the day of sampling, information was also collected on water quality at each plant (Tables 3-4). Data were collected for total organic carbon (TOC) and ultraviolet (UV) absorbance for plant 7 and plant 8 (Table 5). Plants 7 and 8 treated a groundwater that was high in TOC (12-13 mg/L) and in color. Lime softening at plant 7 and plant 8 removed 21-35 % of the TOC and reduced the UV by 38-48 %. Filtration removed another 3-9 % of the TOC. At plant 7, ozonation did not significantly effect the level of TOC, whereas the UV was reduced by another 13-37 %. The overall (cumulative) removal of TOC at plant 7 (due to lime softening, filtration, and ozonation) was 27-33 % and the UV was reduced by 52-61 %. The overall (cumulative) removal of TOC at plant 8 in the lime-softening portion of the plant was 29-39 % and the UV was reduced by 43-54 %. At plant 8, the membrane process reduced both the TOC and the UV by 97-98 %. At plant 8, the plant effluent TOC was 2.5-3.6 mg/L, which approximately matched the relative contributions of TOC from each of the two portions of the plant. The concentration of TOC (2.6-3.5 mg/L) in the distribution system of plant 8 confirmed that this location was receiving membrane treated water.

Table 6 shows the values of miscellaneous other water quality parameters in the raw water of plants 7 and 8. The raw water at each plant contained a moderate or high amount of bromide (the bromide concentrations at plant 7 and plant 8 were 0.12-0.14 and 0.25-0.33 mg/L, respectively). At plant 8, a significant percentage (60-67 %) of the raw-water bromide was rejected by the membrane process.

The raw water also contained a moderate amount of ammonia (0.5-0.7 mg/L as N). It takes 7.6 mg/L of chlorine to breakpoint chlorinate 1.0 mg/L of ammonia-nitrogen. Groundwaters that are high in ammonia are often high in hydrogen sulfide (Krasner et al., 1996), which also exerts a high chlorine demand. When chlorine is added to such groundwaters, typically chloramines are formed, since not all of the ammonia will be breakpoint chlorinated. At plant 8, chloramines were formed during the chlorination of the raw water at the lime-softening portion of the plant and during the chlorination of the membrane effluent (Table 4).

DBPs

Oxyhalides. At plant 7, ozonation did not result in the formation of bromate at or above the minimum reporting level (MRL) of 3 µg/L. Ammonia addition is a method of controlling bromate formation, because the ammonia may be able to tie up the bromide as bromamines (Krasner et al., 1993). At plant 7, 0.9-1.3 mg/L of ammonia-nitrogen was added to the raw water in addition to the 0.6-0.7 mg/L that was naturally present. Ozonation of a water with a free chlorine residual can result in the formation of chlorate. Chlorate was not detected at plant 7, since the free chlorine was converted to chloramines by the ammonia present prior to the addition of ozone.

Table 3. Water quality information at plant 7

Location	pH				Temperature (°C)				Disinfectant Residual ^a (mg/L)			
	12/11/00	3/12/01	9/24/01	1/14/02	12/11/00	3/12/01	9/24/01	1/14/02	12/11/00	3/12/01	9/24/01	1/14/02
Raw water	7.1	7.35	7.3	7.30	25	25	25	25	---	---	---	---
Settled	9.75	9.59	10.1	10.09	25	25	25	25	2.5	---	0.6	ND ^b
Filter eff.	9.60	9.51	9.8	9.96	25	25	25	25	1.4	3.6	0.4	0.9
Ozone eff.	9.23	9.24	9.4	9.55	25	25	25	25	>0.9	2.7	trace	1.0
Plant eff.	8.95	8.91	9.0	9.07	25	25	25	25	5.0	4.8	4.9	4.7
Dist. syst.	8.98	8.95	9.0	9.08	25	25	25	25	4.4	3.6	4.6	4.1
SDS	NA	NA	NA	9.07	NA	NA	NA	25	NA	NA	NA	4.7

^aChloramine residuals^bND = Not detected**Table 4. Water quality information at plant 8**

Location	pH				Temperature (°C)				Disinfectant Residual ^a (mg/L)			
	12/11/00	3/12/01	9/24/01	1/14/02	12/11/00	3/12/01	9/24/01	1/14/02	12/11/00	3/12/01	9/24/01	1/14/02
Raw water	7.05	7.02	7.2	7.19	24.8	24.8	24.6	24.2	---	---	---	---
Lime Softening												
Settled	9.7	10.4	NA	10.52	24.4	25.0	NA	23.9	1.1	0.4	NA	1.6
Filter eff.	9.2	10.0	10.2	10.16	25.6	25.3	24.8	23.9	5.0	3.5+	5.9	3.5+
Membrane Softening												
Memb. eff	5.5	5.38	5.4	5.55	25.0	25.4	23.8	24.4	---	---	---	---
Stripper tower eff.	8.1	7.30	9.1	6.81	25.0	25.2	24.2	25.1	5.5	3.5+	4.7	3.5+
Combined Treated Waters												
Plant eff.	8.8	8.93	9.0	8.75	25.0	26.7	24.3	25.1	4.1	3.5+	4.6	3.5+
Dist. syst.	8.8	8.90	9.0	8.95	25.0	25.5	24.9	25.0	4.1	4.0	4.5	4.2
SDS	8.7	NA	8.8	8.8	23.5	NA	23.0	24.2	3.7	NA	4.3	4.0

^aChloramine residuals

Table 5. TOC and UV removal at plants 7 and 8

Location	TOC (mg/L)	UV ^a (cm ⁻¹)	SUVA ^b (L/mg-m)	Removal/Unit (%)		Removal/Cumulative (%)		Flow (mgd)
				TOC	UV	TOC	UV	
12/11/2000								
Plant 7 Raw	12.7	0.470	3.70	---	---	---	---	
Plant 7 Settled	9.21	0.277	3.01	27%	41%	27%	41%	
Plant 7 Filter Eff.	8.85	0.282	3.19	3.9%	-1.8%	30%	40%	
Plant 7 Ozone Eff.	8.55	0.211	2.47	3.4%	25%	33%	55%	
Plant 7 Dist. Syst.	7.87							
Plant 8 Raw	13.4	0.505	3.77	---	---	---	---	
Plant 8 Settled	8.7	0.262	3.01	35%	48%	35%	48%	
Plant 8 Filter Eff.	8.13	0.233	2.87	6.6%	11%	39%	54%	4.5
Plant 8 Membrane Eff.	0.42	0.01	2.38	97%	98%	97%	98%	6.55
Plant 8 Plant Eff./Measured	3.55							11.05
Plant 8 Plant Eff./Predicted ^c	3.56							
Plant 8 Dist. Syst.	3.47							
3/12/2001								
Plant 7 Raw	12.3	0.458	3.72	---	---	---	---	
Plant 7 Settled	9.28	0.283	3.05	25%	38%	25%	38%	
Plant 7 Filter Eff.	8.96	0.283	3.16	3.4%	0%	27%	38%	
Plant 7 Ozone Eff.	8.52	0.179	2.10	4.9%	37%	31%	61%	
Plant 7 Dist. Syst.	8.42							
Plant 8 Raw	12.8	0.494	3.86	---	---	---	---	
Plant 8 Settled	8.84	0.267	3.02	31%	46%	31%	46%	
Plant 8 Filter Eff.	8.44	0.248	2.94	4.5%	7.1%	34%	50%	3.00
Plant 8 Membrane Eff.	0.3	0.013	4.33	98%	97%	98%	97%	8.41
Plant 8 Plant Eff./Measured	2.9							11.41
Plant 8 Plant Eff./Predicted	2.44							
Plant 8 Dist. Syst.	2.82							
9/24/2001								
Plant 7 Raw	12.7	0.465	3.66	---	---	---	---	
Plant 7 Settled	10.0	0.287	2.86	21%	38%	21%	38%	
Plant 7 Filter Eff.	9.3	0.277	2.97	6.9%	3.5%	27%	40%	
Plant 7 Ozone Eff.	9.2	0.224	2.44	1.6%	19%	28%	52%	
Plant 8 Raw	12.4	0.454	3.67	---	---	---	---	
Plant 8 Settled	9.4	0.268	2.85	24%	41%	24%	41%	
Plant 8 Filter Eff.	8.7	0.257	2.96	7.7%	4.1%	30%	43%	3.3
Plant 8 Membrane Eff.	0.39	0.012	3.08	97%	97%	97%	97%	6.8
Plant 8 Plant Eff./Measured	3.5							10.1
Plant 8 Plant Eff./Predicted	3.1							
Plant 8 Dist. Syst.	3.3							
01/14-16/2002								
Plant 7 Raw	12.6	0.454	3.60	---	---	---	---	
Plant 7 Settled	9.5	0.262	2.76	25%	42%	25%	42%	
Plant 7 Filter Eff.	9.3	0.248	2.68	2.2%	5.3%	26%	45%	
Plant 7 Ozone Eff.	9.2	0.213	2.32	0.9%	13%	27%	53%	
Plant 7 Dist. Syst.	8.8							
Plant 8 Raw	11.3	0.414	3.66	---	---	---	---	
Plant 8 Settled	8.8	0.248	2.82	22%	40%	22%	40%	
Plant 8 Filter Eff.	8.0	0.233	2.90	8.6%	6.0%	29%	44%	3.0
Plant 8 Membrane Eff.	0.28	0.01	3.57	98%	98%	98%	98%	8.6
Plant 8 Plant Eff./Measured	2.5							11.6
Plant 8 Plant Eff./Predicted	2.3							
Plant 8 Dist. Syst.	2.6							

^aUV = Ultraviolet absorbance reported in units of "inverse centimeters" (APHA, 1998)

^bSUVA (L/mg-m) = Specific ultraviolet absorbance = $100 \times \text{UV (cm}^{-1}\text{)}/\text{DOC (mg/L)}$ or $\text{UV (m}^{-1}\text{)}/\text{DOC (mg/L)}$, where DOC = dissolved organic carbon, which typically = 90-95% TOC (used TOC values in calculating SUVA) (e.g., $\text{UV} = 0.470/\text{cm} = 0.470/(0.01 \text{ m}) = 47.0/\text{m}$, $\text{DOC} = 12.7 \text{ mg/L}$, $\text{SUVA} = (47.0 \text{ m}^{-1})/(12.7 \text{ mg/L}) = 3.70 \text{ L/mg-m}$)

^c(lime softening flow)*(filter effluent TOC) + (membrane softening flow)*(membrane effluent TOC) = plant effluent TOC

Table 6. Miscellaneous water quality parameters at plants 7 and 8

Location	Bromide (mg/L)	Alkalinity (mg/L)	Ammonia (mg/L as N)	Chlorine Demand ^a (mg/L)
12/11/2000				
Plant 7 Raw	0.12	265	0.73	5.5
Plant 8 Raw	0.33	249	0.62	4.7
Plant 8 Membrane Eff.	0.11			
Plant 8 Bromide Rejection (%)	66%			
3/12/2001				
Plant 7 raw water	0.14	265	0.69	5.2
Plant 8 raw water	0.3	250	0.62	4.7
Plant 8 membrane effluent	0.1			
Plant 8 bromide rejection (%)	67%			
9/24/2001				
Plant 7 Raw	0.14	264	0.62	4.7
Plant 8 Raw	0.25	236	0.48	3.6
Plant 8 Membrane Eff.	0.1			
Plant 8 Bromide Rejection (%)	60%			
01/14-16/2002				
Plant 7 Raw	0.14	130	0.67	5.1
Plant 8 Raw	0.27	236	0.46	3.5
Plant 8 Membrane Eff.	0.1			
Plant 8 Bromide Rejection (%)	63%			

^aChlorine demand from ammonia = 7.6 x ammonia (mg/L as N)

Biodegradable Organic Matter. Ozone can convert natural organic matter in water to carboxylic acids (Kuo et al., 1996) and other assimilable organic carbon (AOC) (van der Kooij et al., 1982). Table 7 shows the carboxylic acid and AOC data for all four sampling dates at plant 7. In addition, Figure 3 shows the AOC results for the December 2000, March 2001, and September 2001 samplings. Low concentrations of AOC and certain carboxylic acids were detected in the raw water at plant 7. Those levels increased somewhat after chloramination and increased significantly after ozonation (except for the AOC in September 2001).

Because AOC data are expressed in units of micrograms of carbon per liter ($\mu\text{g C/L}$), the carboxylic acid data were converted to the same units. A portion of the molecular weight (MW) of each carboxylic acid is due to carbon atoms (i.e., 27-49 %) and the remainder is due to oxygen and hydrogen atoms. The sums of the five carboxylic acids (on a $\mu\text{g C/L}$ basis) were compared to the AOC data. On a median basis for each sample date, 23-30 % of the AOC was accounted for by the carboxylic acids. The amount of AOC that was accounted for by carboxylic acids in the ozone contactor effluent was typically greater than the percentage accounted for in the chloraminated water. Although carboxylic acids have been shown to be ozone by-products, they have not been shown to be by-products of chloramines. However, in other research (Jacangelo et

Table 7. Formation and removal of carboxylic acids and AOC at plant 7

Location	Concentration ^a (µg/L)					Concentration (µg C/L)							Sum/ AOC
	Acetate	Propionate	Formate	Pyruvate	Oxalate	Acetate	Propionate	Formate	Pyruvate	Oxalate	Sum	AOC	
12/11/2000													
Plant 7 Raw	35	ND ^b	37	NR ^c	21	14	ND	9.8	NR	5.8	30	111	27%
Plant 7 Filter Eff.	50	ND	50	NR	54	20	ND	13	NR	15	48	269	18%
Plant 7 Ozone Eff.	150	ND	247	NR	324	61	ND	66	NR	88	215	577	37%
												median	27%
3/12/2001													
Plant 7 Raw	ND	ND	23	ND	ND	ND	ND	6.1	ND	ND	6.1	112	5%
Plant 7 Filter Eff.	41	ND	59	44	60	17	ND	16	18	16	67	277	24%
Plant 7 Ozone Eff.	223	ND	369	52	657	91	ND	98	22	179	390	1031	38%
												median	24%
9/24/2001													
Plant 7 Raw	7.1	ND	8.5	ND	5.7	2.9	ND	2.3	ND	1.6	6.7	102	7%
Plant 7 Filter Eff.	37	ND	37	17	35	15	ND	10	7.0	10	41	197	21%
Plant 7 Ozone Eff.	102	5.2	177	24	235	41	2.6	47	10	64	165	203	81%
												median	23%
1/14/2002													
Plant 7 Raw	11	ND	73	ND	19	4.6	ND	19	ND	5.1	29	98	30%
Plant 7 Filter Eff.	28	ND	122	27	37	11	ND	33	11	10	65	147	44%
Plant 7 Ozone Eff.	102	ND	223	40	279	41	ND	59	16	76	194	657	29%
												median	30%
Formula	CH ₃ COO ⁻	CH ₃ CH ₂ COO ⁻	HCOO ⁻	CH ₃ COCOO ⁻	C ₂ O ₄ ²⁻								
MW (gm/mole)	59	73	45	87	88								
C portion (gm/mole)	24	36	12	36	24								
C% of MW	41%	49%	27%	41%	27%								

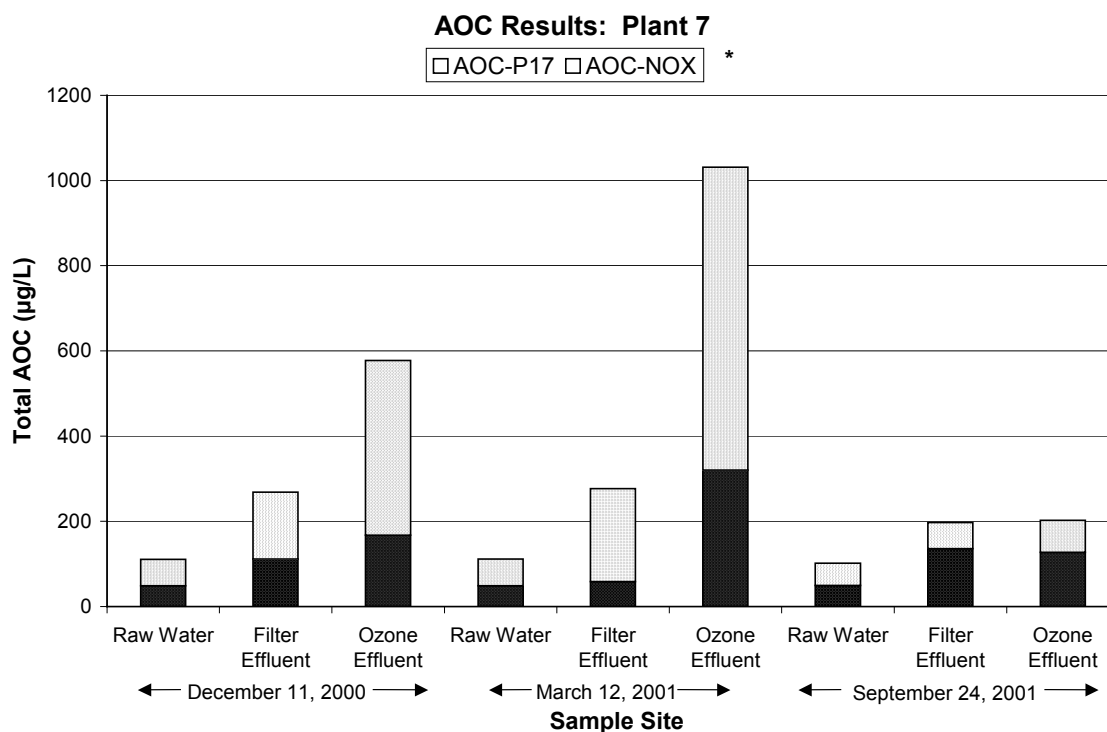
^aMethod detection limit (MDL) = 3 µg/L; reporting detection level (RDL) = 15 µg/L

Values > MDL but < RDL shown in italics

^bND = Not detected, value is < RDL

^cNR = Not reported, quality control problem

Figure 3



*AOC evaluated with two test bacteria: *Pseudomonas fluorescens* P-17 and *Spirillum* NOX

al., 1989), chloramines have been shown to be capable of producing aldehydes—other ozone by-products—at lower levels than that produced during ozonation.

Halogenated Organic and Other Nonhalogenated Organic DBPs. Tables 8 and 9 (12/11/00), Tables 11 and 12 (3/12/01), Tables 14 and 15 (9/24/01), and Tables 17 and 18 (1/14-16/02) show results for the halogenated organic DBPs that were analyzed at Metropolitan Water District of Southern California (MWDSC). Table 10 (12/11/00 [plant 7] and Table 16 (9/24/01 [plant 8]) show results from broadscreen DBP analyses conducted at the U.S. Environmental Protection Agency (USEPA). Table 13 (3/12/01) and Table 19 (1/14-16/02) show results for additional target DBPs that were analyzed for at the University of North Carolina (UNC). Tables 20-21 (1/14-16/02) show results for halogenated furanones that were analyzed at UNC.

Summary of tables for halogenated organic and other nonhalogenated organic DBPs

DBP Analyses (Laboratory)	12/11/00	3/12/01	9/24/01	1/14-16/02
Halogenated organic DBPs (MWDSC)	Tables 8-9	Tables 11-12	Tables 14-15	Tables 17-18
Additional target DBPs (UNC)		Table 13		Table 19
Halogenated furanones (UNC)				Tables 20-21
Broadscreen analysis (USEPA)	Table 10 ^a		Table 16 ^b	

^aPlant 7

^bPlant 8

Table 8. DBP results at plant 7 (12/11/00)

12/11/2000	MRL ^a	Plant 7 ^b						
Compound	µg/L	Raw	Settled	Filt Eff	O3 Eff	Plant Eff	DS	SDS
<u>Halomethanes</u>								
Chloromethane	0.15	ND ^d		ND		ND	ND	ND
Bromomethane	0.20	ND		ND		ND	ND	ND
Bromochloromethane	0.14	ND		ND		ND	ND	ND
Dibromomethane	0.11	ND		ND		ND	ND	ND
Chloroform ^e	0.10	ND	10	17	16	17	16	17
Bromodichloromethane ^e	0.10	ND	1	1	NR ^f	1	1	1
Dibromochloromethane ^e	0.12	ND	ND	0.1	NR	0.1	0.1	0.1
Bromoform ^e	0.12	ND	ND	ND	ND	ND	ND	0.3
THM4 ^g		ND	11	18	NR	18	17	18
Dichloriodomethane	0.10	ND	ND	ND	ND	0.3	ND	0.2
Bromochloriodomethane	3	ND	NR	ND	NR	ND	ND	<1 ^h
Dibromiodomethane	0.64	ND	ND	ND	ND	ND	ND	ND
Chlorodiodomethane	0.10	ND	ND	0.2	ND	ND	ND	0.2
Bromodiodomethane	0.12	ND	ND	ND	ND	ND	ND	ND
Iodoform	0.14	ND	ND	ND	ND	ND	ND	ND
Carbon tetrachloride	0.06	ND		ND		ND	0.07	ND
<u>Haloacetic acids</u>								
Monochloroacetic acid ^e	2		ND	ND		2.2	ND	2.6
Monobromoacetic acid ^e	1		1.2	1.3		1.6	1.4	1.5
Dichloroacetic acid ^e	1		6.5	12		20	22	27
Bromochloroacetic acid ^e	1		ND	1.1		1.7	1.7	2.0
Dibromoacetic acid ^e	1		ND	ND		ND	1.0	ND
Trichloroacetic acid ^e	1		1.1	3.2		3.4	3.0	3.3
Bromodichloroacetic acid	1		ND	ND		ND	ND	ND
Dibromochloroacetic acid	1		ND	ND		ND	ND	ND
Tribromoacetic acid	2		ND	ND		ND	ND	ND
HAA5 ⁱ			8.8	16		27	27	34
HAA9 ^j			8.8	17		29	29	36
DXAA ^k			6.5	13		22	24	29
TXAA ^l			1.1	3.2		3.4	3.0	3.3
<u>Haloacetonitriles</u>								
Chloroacetonitrile	0.10	ND	ND	ND	ND	ND	ND	ND
Bromoacetonitrile	0.10	ND	ND	ND	ND	ND	ND	ND
Dichloroacetonitrile ^e	0.10	ND	ND	ND	0.2	0.3	ND	ND
Bromochloroacetonitrile ^e	0.10	ND	ND	ND	ND	ND	ND	ND
Dibromoacetonitrile ^e	0.10	ND	ND	ND	ND	ND	ND	ND
Trichloroacetonitrile ^e	0.10	ND	ND	ND	ND	ND	ND	ND
<u>Haloacetaldehydes</u>								
Dichloroacetaldehyde	0.16	ND	1	3	12	14	15	16
Bromochloroacetaldehyde ^m								
Chloral hydrate ^e	0.20	ND	ND	ND	0.3	0.5	0.5	0.5
Tribromoacetaldehyde	0.10	ND	ND	ND	ND	ND	ND	ND

Table 8 (continued)

12/11/2000	MRL ^a	Plant 7 ^b						
Compound	µg/L	Raw	Settled	Filt Eff	O3 Eff	Plant Eff	DS	SDS
<u>Haloketones</u>								
Chloropropanone	0.10	ND	ND	0.3	0.6	2	1	2
1,1-Dichloropropanone ^e	0.10	ND	ND	0.3	0.5	2	ND	ND
1,3-Dichloropropanone	0.10	ND	ND	ND	ND	ND	ND	ND
1,1-Dibromopropanone	3	ND		ND		ND	ND	ND
1,1,1-Trichloropropanone ^e	0.10	ND	ND	ND	ND	ND	ND	ND
1,1,3-Trichloropropanone	0.10	ND	ND	ND	ND	ND	ND	ND
1-Bromo-1,1-dichloropropanone	3	ND		ND		ND	ND	ND
1,1,1-Tribromopropanone	3	ND		ND		ND	ND	ND
1,1,3-Tribromopropanone	3	ND		ND		ND	ND	ND
1,1,3,3-Tetrachloropropanone	0.10	ND	ND	0.1	ND	ND	ND	ND
1,1,3,3-Tetrabromopropanone	0.10	ND	0.2	0.2	0.1	0.1	ND	ND
<u>Halonitromethanes</u>								
Bromonitromethane	0.10	ND	ND	ND	ND	ND	ND	0.1
Dichloronitromethane	3	NR		NR		NR	NR	NR
Dibromonitromethane	0.10	ND	ND	ND	ND	ND	ND	ND
Chloropicrin ^e	0.10	ND	ND	ND	ND	ND	ND	ND
<u>Miscellaneous Compounds</u>								
Methyl ethyl ketone	1.90	ND		ND		ND	ND	ND
Methyl <i>tertiary</i> butyl ether	0.16	ND		ND		ND	ND	ND
Benzyl chloride	0.50	ND	NR	ND	NR	ND	ND	ND

^aMRL = Minimum reporting level, which equals method detection limit (MDL)

or lowest calibration standard or concentration of blank

^bPlant 7 sampled at (1) raw water, (2) settled water, (3) filter effluent (FE), (4) effluent of ozone contactor, (5) plant effluent (PE), (6) distribution system (DS), and (7) SDS testing of plant effluent

^cPlant 8 sampled at (1) raw water; lime softening portion of plant at (2) settled water, (3) filter effluent; membrane softening portion of plant at (4) effluent of stripper towers; combined treated waters at (5) plant effluent, (6) DS, and (7) SDS testing of plant effluent

^dND = Not detected at or above MRL

^eDBP in the Information Collection Rule (ICR) (note: some utilities collected data for all 9 haloacetic acids for the ICR, but monitoring for only 6 haloacetic acids was required)

^fNR = Not reported, due to interference problem on gas chromatograph or to problem with quality assurance

^gTHM4 = Sum of 4 THMs (chloroform, bromodichloromethane, dibromochloromethane, bromoform)

^h<1: Concentration less than lowest calibration standard (i.e., 1 µg/L)

ⁱHAA5 = Sum of 5 haloacetic acids (monochloro-, monobromo-, dichloro-, dibromo-, trichloroacetic acid)

^jHAA9 = Sum of 9 haloacetic acids

^kDXAA = Sum of dihaloacetic acids (dichloro-, bromochloro-, dibromoacetic acid)

^lTXAA = Sum of trihaloacetic acids (trichloro-, bromodichloro-, dibromochloro-, tribromoacetic acid)

^mBromochloroacetaldehyde and chloral hydrate co-eulite; result = sum of 2 DBPs

Table 9. DBP results at plant 8 (12/11/00)

12/11/2000	MRL ^a	Plant 8 ^c						
Compound	µg/L	Raw	Settled	Filt Eff	Tower Eff	Plant Eff	DS	SDS
<u>Halomethanes</u>								
Chloromethane	0.15			0.2	ND	ND	ND	ND
Bromomethane	0.20			ND	ND	ND	ND	ND
Bromochloromethane	0.14			ND	ND	ND	ND	ND
Dibromomethane	0.11			ND	ND	ND	ND	ND
Chloroform ^e	0.10	0.6	15	90	1	57	61	61
Bromodichloromethane ^e	0.10	ND	NR	22	1	9	9	9
Dibromochloromethane ^e	0.12	ND	NR	3	0.5	1	1	1
Bromoform ^e	0.12	ND	ND	0.4	0.5	0.8	0.9	0.8
THM4 ^g		0.6	NR	115	3	68	72	72
Dichloroiodomethane	0.10	ND	ND	2	0.8	1	1	1
Bromochloroiodomethane	3	ND	NR	<1	<1	<1	<1	<1
Dibromoiodomethane	0.64	ND	ND	<1	<1	<1	<1	<1
Chlorodiiodomethane	0.10	ND	ND	ND	ND	ND	ND	ND
Bromodiiodomethane	0.12	ND	ND	ND	ND	ND	ND	ND
Iodoform	0.14	ND	ND	ND	ND	ND	ND	ND
Carbon tetrachloride	0.06			ND	ND	ND	ND	ND
<u>Haloacetic acids</u>								
Monochloroacetic acid ^e	2		ND	ND	ND	ND	ND	ND
Monobromoacetic acid ^e	1		1.3	1.7	1.3	1.5	1.4	1.4
Dichloroacetic acid ^e	1		7.6	35	1.7	21	20	24
Bromochloroacetic acid ^e	1		1.0	6.3	ND	3.2	2.7	4.4
Dibromoacetic acid ^e	1		ND	1.0	1.1	ND	1.0	1.2
Trichloroacetic acid ^e	1		1.8	15	ND	5.8	5.0	6.4
Bromodichloroacetic acid	1		ND	3.2	ND	1.1	1.1	1.3
Dibromochloroacetic acid	1		ND	1.0	ND	ND	ND	ND
Tribromoacetic acid	2		ND	ND	ND	ND	ND	ND
HAA5 ^j			11	53	4.1	28	27	33
HAA9 ^j			12	64	4.1	33	31	38
DXAA ^k			8.6	42	2.8	24	23	29
TXAA ^l			1.8	19	ND	6.9	6.1	7.7
<u>Haloacetonitriles</u>								
Chloroacetonitrile	0.10	ND	ND	ND	ND	ND	ND	ND
Bromoacetonitrile	0.10	ND	ND	ND	ND	ND	ND	ND
Dichloroacetonitrile ^e	0.10	ND	ND	8	0.2	0.6	0.6	0.2
Bromochloroacetonitrile ^e	0.10	ND	ND	2	0.2	0.4	0.4	0.2
Dibromoacetonitrile ^e	0.10	ND	ND	0.2	0.2	0.2	0.2	0.1
Trichloroacetonitrile ^e	0.10	ND	ND	ND	ND	ND	ND	ND
<u>Haloacetaldehydes</u>								
Dichloroacetaldehyde	0.16	ND	1	3	ND	2	1	3
Bromochloroacetaldehyde ^m								
Chloral hydrate ^e	0.20	ND	ND	13	0.2	1.6	1.5	0.2
Tribromoacetaldehyde	0.10	ND	ND	ND	ND	ND	ND	ND

Table 9 (continued)

12/11/2000	MRL ^a	Plant 8 ^c						
Compound	µg/L	Raw	Settled	Filt Eff	Tower Eff	Plant Eff	DS	SDS
Haloketones								
Chloropropanone	0.10	ND	ND	0.3	ND	0.3	0.2	0.3
1,1-Dichloropropanone ^e	0.10	ND	ND	0.4	ND	0.2	0.2	0.2
1,3-Dichloropropanone	0.10	ND	ND	ND	ND	ND	ND	ND
1,1-Dibromopropanone	3			ND	ND	ND	ND	ND
1,1,1-Trichloropropanone ^e	0.10	ND	ND	0.9	0.1	ND	ND	ND
1,1,3-Trichloropropanone	0.10	ND	0.2	0.2	ND	0.1	0.1	ND
1-Bromo-1,1-dichloropropanone	3			ND	ND	ND	ND	ND
1,1,1-Tribromopropanone	3			ND	ND	ND	ND	ND
1,1,3-Tribromopropanone	3			ND	ND	ND	ND	ND
1,1,3,3-Tetrachloropropanone	0.10	ND	ND	ND	ND	ND	ND	ND
1,1,3,3-Tetrabromopropanone	0.10	0.1	ND	0.1	ND	0.1	ND	0.1
Halonitromethanes								
Bromonitromethane	0.10	ND	ND	ND	ND	ND	ND	ND
Dichloronitromethane	3			NR	NR	NR	NR	NR
Dibromonitromethane	0.10	ND	ND	ND	ND	ND	ND	ND
Chloropicrin ^e	0.10	ND	ND	0.4	ND	0.4	0.4	0.4
Miscellaneous Compounds								
Methyl ethyl ketone	1.90			ND	ND	ND	ND	ND
Methyl <i>tertiary</i> butyl ether	0.16			ND	ND	ND	ND	ND
Benzyl chloride	0.50	ND	NR	ND	ND	ND	ND	ND

Table 10. Occurrence of other DBPs^a at plant 7 (12/11/00)

Compound	FE	PE	Compound	FE	PE
Halomethanes			Haloketones		
<i>Bromodichloromethane^b</i>	x	x	1,1-Dichloropropanone	x	x
<i>Dibromochloromethane</i>	x	x	1-Bromo-1-chloropropanone	x	x
<i>Bromoform</i>	x	x	1,1,1-Trichloropropanone	x	x
<i>Dichloroiodomethane</i>	x	x	1,1,3-Trichloropropanone	x	x
<i>Bromochloroiodomethane</i>	x	x	1-Bromo-1,1-dichloropropanone	x	x
<i>Diiodochloromethane</i>	x	x	<i>1,1,3-Tribromopropanone</i>	x	x
Haloacids			1,1,3,3-Tetrachloropropanone	x	x
<i>Dichloroacetic acid</i>	x	x	1-Bromo-1,3,3-trichloropropanone	x	x
<i>Bromochloroacetic acid</i>	x	x	<i>1,1-Dibromo-3,3-dichloropropanone</i>	x	x
<i>Dibromoacetic acid</i>	x	x	<i>1,3-Dibromo-1,3-dichloropropanone</i>	-	x
<i>Trichloroacetic acid</i>	x	x	<i>1,1,3-Tribromo-3-chloropropanone</i>	-	x
Haloacetonitriles			<i>1,1,3,3-Tetrabromopropanone</i>	-	x
Bromochloroacetonitrile	x	x	Pentachloropropanone	x	x
Dibromoacetonitrile	x	x	Miscellaneous Halogenated DBPs		
Haloaldehydes			Hexachlorocyclopentadiene	x	x
Dibromoacetaldehyde	-	x	Bromopentachlorocyclopentadiene	x	x
2-Bromo-2-methylpropanal	x	x	Non-halogenated DBPs		
Halonitromethanes			<i>Formaldehyde</i>	-	x
Dichloronitromethane	x	x	<i>Acetone</i>	-	x
<i>Bromochloronitromethane</i>	-	x	<i>Glyoxal</i>	-	x
			<i>Methyl glyoxal</i>	-	x

^aDBPs detected by broadscreen gas chromatography/mass spectrometry (GC/MS) technique^bCompounds listed in italics were confirmed through the analysis of authentic standards; haloacids and non-halogenated carboxylic acids identified as their methyl esters.

Table 11. DBP results at plant 7 (3/12/01)

03/12/2001	MRL ^a	Plant 7 ^b						
Compound	µg/L	Raw	Settled	Filt Eff	O3 Eff	Plant Eff	DS	SDS
<u>Halomethanes</u>								
Chloromethane	0.15	ND ^d		ND		ND	ND	ND
Bromomethane	0.20	ND		ND		ND	ND	ND
Bromochloromethane	0.14	ND		ND		ND	ND	ND
Dibromomethane	0.11	ND		ND		ND	ND	ND
Chloroform ^e	0.1	ND	8	15	14	13	21	24
Bromodichloromethane ^e	0.1	ND	0.8	3	3	2	3	4
Dibromochloromethane ^e	0.10	ND	ND	ND	ND	ND	ND	0.2
Bromoform ^e	0.12	ND	ND	ND	ND	ND	ND	ND
THM4 ^g		ND	9	18	17	15	24	27
Dichloriodomethane	0.25	ND	NR ^f	ND	NR	ND	ND	ND
Bromochloriodomethane	3	ND	NR	ND	NR	ND	ND	ND
Dibromiodomethane	0.60	ND	ND	ND	ND	ND	ND	ND
Chlorodiiodomethane	0.51	ND	ND	ND	ND	ND	ND	ND
Bromodiiodomethane	0.56	ND	ND	ND	ND	ND	ND	ND
Iodoform	0.54	ND	ND	ND	ND	ND	ND	ND
Carbon tetrachloride	0.06	ND		0.2		0.4	0.5	0.4
Tribromochloromethane	0.1	ND	ND	ND	ND	ND	ND	ND
<u>Haloacetic acids</u>								
Monochloroacetic acid ^e	2		ND	ND		2.8	2.6	3.6
Monobromoacetic acid ^e	1		ND	ND		ND	ND	ND
Dichloroacetic acid ^e	1		7.4	12		22	20	32
Bromochloroacetic acid ^e	1		ND	1.0		1.7	1.5	2.1
Dibromoacetic acid ^e	1		ND	ND		ND	ND	ND
Trichloroacetic acid ^e	1		1.2	4.0		5.1	3.5	5.6
Bromodichloroacetic acid	1		ND	ND		ND	ND	ND
Dibromochloroacetic acid	1		ND	ND		ND	ND	ND
Tribromoacetic acid	2		ND	ND		ND	ND	ND
HAA5 ^j			8.6	16		30	26	41
HAA9 ^j			8.6	17		32	28	43
DXAA ^k			7.4	13		24	22	34
TXAA ^l			1.2	4.0		5.1	3.5	5.6
<u>Haloacetonitriles</u>								
Chloroacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND
Bromoacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND
Dichloroacetonitrile ^e	0.10	ND	ND	0.2	0.2	0.5	0.2	0.3
Bromochloroacetonitrile ^e	0.1	ND	ND	ND	ND	ND	ND	ND
Dibromoacetonitrile ^e	0.17	ND	ND	ND	ND	ND	ND	ND
Trichloroacetonitrile ^e	0.1	ND	ND	ND	ND	ND	ND	ND
<u>Haloacetaldehydes</u>								
Dichloroacetaldehyde	0.16	ND	0.8	3	6	9	9	10
Bromochloroacetaldehyde	0.1	ND	ND	0.2	ND	0.1	ND	ND
Chloral hydrate ^e	0.1	ND	ND	0.1	ND	0.7	0.5	0.6
Tribromoacetaldehyde	0.1	ND	ND	ND	ND	ND	ND	ND

Table 11 (continued)

03/12/2001	MRL ^a	Plant 7 ^b						
Compound	µg/L	Raw	Settled	Filt Eff	O3 Eff	Plant Eff	DS	SDS
<u>Haloketones</u>								
Chloropropanone	0.5	ND	ND	ND	ND	0.7	ND	ND
1,1-Dichloropropanone ^e	0.11	ND	ND	0.2	0.5	1	0.5	0.8
1,3-Dichloropropanone	0.10	ND	ND	ND	ND	ND	ND	ND
1,1-Dibromopropanone	3	ND		ND		ND	ND	ND
1,3-Dibromopropanone	3	ND		ND		ND	ND	ND
1,1,1-Trichloropropanone ^e	0.10	ND	ND	ND	ND	ND	ND	ND
1,1,3-Trichloropropanone	0.11	ND	ND	ND	ND	ND	ND	ND
1-Bromo-1,1-dichloropropanone	3	ND		ND		ND	ND	ND
1,1,1-Tribromopropanone	3	ND		ND		ND	ND	ND
1,1,3-Tribromopropanone	3	ND		ND		ND	ND	ND
1,1,3,3-Tetrachloropropanone	0.12	ND	ND	ND	ND	ND	ND	ND
1,1,1,3-Tetrachloropropanone	3	ND		ND		ND	ND	ND
1,1,3,3-Tetrabromopropanone	0.5	ND	ND	ND	ND	ND	ND	ND
<u>Halonitromethanes</u>								
Bromonitromethane	0.1	ND	ND	ND	ND	ND	ND	ND
Dichloronitromethane	3	ND		ND		ND	ND	ND
Bromochloronitromethane	3	ND		ND		ND	ND	ND
Dibromonitromethane	0.12	ND	ND	ND	ND	ND	ND	ND
Chloropicrin ^e	0.1	ND	ND	ND	ND	ND	ND	ND
<u>Miscellaneous Compounds</u>								
Methyl ethyl ketone	1.90	ND		ND		ND	ND	ND
Methyl <i>tertiary</i> butyl ether	0.16	ND		ND		ND	ND	ND
Benzyl chloride	2	ND	ND	ND	ND	ND	ND	ND

Table 12. DBP results at plant 8 (3/12/01)

03/12/2001	MRL ^a	Plant 8 ^c						
Compound	µg/L	Raw	Settled	Filt Eff	Tower Eff	Plant Eff	DS	SDS
<u>Halomethanes</u>								
Chloromethane	0.15			ND	ND	ND	ND	ND
Bromomethane	0.20			ND	ND	ND	ND	ND
Bromochloromethane	0.14			ND	ND	ND	ND	ND
Dibromomethane	0.11			ND	ND	ND	ND	ND
Chloroform ^e	0.1	ND	14	81	1	41	42	42
Bromodichloromethane ^e	0.1	ND	3	15	0.6	7	7	7
Dibromochloromethane ^e	0.10	ND	0.2	2	0.2	2	2	2
Bromoform ^e	0.12	ND	ND	ND	ND	ND	ND	ND
THM4 ^g		ND	17	98	2	50	51	50
Dichloriodomethane	0.25	NR	NR	2	ND	0.7	0.6	0.7
Bromochloriodomethane	3	NR	NR	<1 ^h	ND	<1	<1	<1
Dibromiodomethane	0.60	ND	ND	ND	ND	ND	ND	ND
Chlorodiiodomethane	0.51	ND	ND	ND	ND	ND	ND	ND
Bromodiiodomethane	0.56	ND	ND	ND	ND	ND	ND	ND
Iodoform	0.54	ND	ND	ND	ND	ND	ND	ND
Carbon tetrachloride	0.06			0.7	ND	0.5	0.5	0.4
Tribromochloromethane	0.1	ND	ND	ND	ND	ND	ND	ND
<u>Haloacetic acids</u>								
Monochloroacetic acid ^e	2		ND	ND	2.4	ND	2.2	ND
Monobromoacetic acid ^e	1		ND	ND	ND	ND	ND	ND
Dichloroacetic acid ^e	1		6.3	36	1.0	14	14	15
Bromochloroacetic acid ^e	1		1.0	3.8	ND	2.0	2.2	2.3
Dibromoacetic acid ^e	1		ND	ND	ND	ND	ND	ND
Trichloroacetic acid ^e	1		1.3	9.1	ND	2.5	2.4	2.5
Bromodichloroacetic acid	1		ND	1.6	ND	ND	ND	ND
Dibromochloroacetic acid	1		ND	ND	ND	ND	ND	ND
Tribromoacetic acid	2		ND	ND	ND	ND	ND	ND
HAA5 ^j			7.6	45	3.4	17	19	18
HAA9 ^j			8.6	51	3.4	19	21	20
DXAA ^k			7.3	40	1.0	16	16	17
TXAA ^l			1.3	11	ND	2.5	2.4	2.5
<u>Haloacetonitriles</u>								
Chloroacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND
Bromoacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND
Dichloroacetonitrile ^e	0.10	ND	ND	3	0.1	0.5	0.5	0.2
Bromochloroacetonitrile ^e	0.1	ND	ND	ND	ND	ND	ND	ND
Dibromoacetonitrile ^e	0.17	ND	ND	ND	ND	ND	ND	ND
Trichloroacetonitrile ^e	0.1	ND	ND	ND	ND	ND	ND	ND
<u>Haloacetaldehydes</u>								
Dichloroacetaldehyde	0.16	0.2	0.3	0.8	ND	0.7	0.7	1
Bromochloroacetaldehyde	0.1	ND	ND	ND	ND	ND	ND	ND
Chloral hydrate ^e	0.1	ND	ND	5.7	0.5	0.4	0.4	0.3
Tribromoacetaldehyde	0.1	ND	ND	ND	ND	ND	ND	ND

Table 12 (continued)

03/12/2001	MRL ^a	Plant 8 ^c						
Compound	µg/L	Raw	Settled	Filt Eff	Tower Eff	Plant Eff	DS	SDS
<u>Haloketones</u>								
Chloropropanone	0.5	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloropropanone ^e	0.11	ND	ND	0.3	ND	0.1	0.1	0.1
1,3-Dichloropropanone	0.10	ND	ND	ND	ND	ND	ND	ND
1,1-Dibromopropanone	3			ND	ND	ND	ND	ND
1,3-Dibromopropanone	3			ND	ND	ND	ND	ND
1,1,1-Trichloropropanone ^e	0.10	ND	ND	0.2	ND	ND	ND	ND
1,1,3-Trichloropropanone	0.11	ND	ND	ND	ND	ND	ND	ND
1-Bromo-1,1-dichloropropanone	3			ND	ND	ND	ND	ND
1,1,1-Tribromopropanone	3			ND	ND	ND	ND	ND
1,1,3-Tribromopropanone	3			ND	ND	ND	ND	ND
1,1,3,3-Tetrachloropropanone	0.12	ND	ND	ND	ND	ND	ND	ND
1,1,1,3-Tetrachloropropanone	3			ND	ND	ND	ND	ND
1,1,3,3-Tetrabromopropanone	0.5	ND	ND	ND	ND	ND	ND	ND
<u>Halonitromethanes</u>								
Bromonitromethane	0.1	ND	ND	ND	ND	0.3	0.3	0.1
Dichloronitromethane	3			ND	ND	ND	ND	ND
Bromochloronitromethane	3			ND	ND	ND	ND	ND
Dibromonitromethane	0.12	ND	ND	ND	ND	ND	ND	ND
Chloropicrin ^e	0.1	ND	ND	0.2	ND	0.1	0.1	0.2
<u>Miscellaneous Compounds</u>								
Methyl ethyl ketone	1.90			ND	ND	ND	ND	ND
Methyl <i>tertiary</i> butyl ether	0.16			0.9	ND	ND	ND	ND
Benzyl chloride	2	ND	ND	ND	ND	ND	ND	ND

Table 13. Additional target DBP results (µg/L) at plants 7 and 8 (3/12/01)

3/12/01	Plant 7 ^a						Plant 8 ^a					
Compound	Raw	FE	OE	PE	DS	SDS	Raw	FE	STE	PE	DS	SDS
Monochloroacetaldehyde	0	0.2	1.2	0.7	0.5	0.5	0	0	0	0	0	0
Dichloroacetaldehyde	0	2.4	4.4	6.8	7.6	8.6	0.1	0.7	0	0.5	0.6	0.6
Bromochloroacetaldehyde												
3,3-Dichloropropenoic acid	0.6				0.4		0				0	
Bromochloromethylacetate	0				0		0				0	
2,2-Dichloroacetamide	0	0.2	0.1	1.8	2.5	3.0	0	4.0	0	2.1	2.2	3.4
TOX (µg/L as Cl ⁻)	24.2	205	127	203	121	207	33.0	459	41	142	157	130
Cyanoformaldehyde	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
5-Keto-1-hexanal	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
6-Hydroxy-2-hexanone	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Dimethylglyoxal	0.4	0.2	4.0	3.5	1.4	1.9	0.3	<0.1	<0.1	<0.1	<0.1	<0.1
<i>trans</i> -2-Hexenal	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

^aPlant 7 or plant 8 sampled at (1) raw water, (2) filter effluent (FE), (3) ozone contactor effluent (OE) or stripper tower effluent (STE), (4) finished water at plant effluent (PE), (5) distribution system (DS) at average detention time, and (6) SDS sample.

Table 14. DBP results at plant 7 (9/24/01)

09/24/2001	MRL ^a	Plant 7 ^b						
Compound	µg/L	Raw	Settled	Filt Eff	O3 Eff	Plant Eff	DS	SDS
<u>Halomethanes</u>								
Chloromethane	0.2	ND ^d		ND		ND	0.2	ND
Bromomethane	0.2	ND		ND		ND	ND	ND
Bromochloromethane	0.5	ND		ND		ND	ND	ND
Dibromomethane	0.5	ND		ND		ND	ND	ND
Chloroform ^e	0.1	ND	3	3	3	7	11	12
Bromodichloromethane ^e	0.1	ND	0.3	0.3	0.4	1	1	1
Dibromochloromethane ^e	0.1	ND	ND	ND	ND	0.1	0.1	0.2
Bromoform ^e	0.1	ND	ND	ND	ND	ND	ND	ND
THM4 ^g		ND	3	3	3	8	12	13
Dichloriodomethane	0.5	ND	NR ^f	ND	NR	ND	0.6	0.6
Bromochloriodomethane	0.25	ND	NR	ND	NR	ND	ND	ND
Dibromiodomethane	0.52	ND	ND	ND	ND	ND	ND	ND
Chlorodiiodomethane	0.1	ND	ND	ND	ND	ND	ND	ND
Bromodiiodomethane	0.5	ND	ND	ND	ND	ND	ND	ND
Iodoform	0.1	ND	ND	ND	ND	ND	ND	ND
Carbon tetrachloride	0.2	ND		ND		ND	ND	ND
Tribromochloromethane	0.5	ND	ND	ND	ND	ND	ND	ND
<u>Haloacetic acids</u>								
Monochloroacetic acid ^e	2		ND	ND		4.2	3.7	4.4
Monobromoacetic acid ^e	1		ND	ND		ND	ND	ND
Dichloroacetic acid ^e	1		4.7	4.2		16	16	20
Bromochloroacetic acid ^e	1		ND	ND		1.9	1.6	1.8
Dibromoacetic acid ^e	1		ND	ND		ND	ND	ND
Trichloroacetic acid ^e	1		1.1	1.1		2.0	2.5	2.3
Bromodichloroacetic acid	1		ND	ND		ND	ND	ND
Dibromochloroacetic acid	1		ND	ND		ND	ND	ND
Tribromoacetic acid	2		ND	ND		ND	ND	ND
HAA5 ⁱ			5.8	5.3		22	22	27
HAA9 ^j			5.8	5.3		24	24	29
DXAA ^k			4.7	4.2		18	18	22
TXAA ^l			1.1	1.1		2.0	2.5	2.3
<u>Haloacetoneitriles</u>								
Chloroacetoneitrile	0.1	ND	ND	ND	ND	ND	ND	ND
Bromoacetoneitrile	0.1	ND	ND	ND	ND	ND	ND	ND
Dichloroacetoneitrile ^e	0.1	ND	0.3	0.1	0.2	0.6	0.6	0.3
Bromochloroacetoneitrile ^e	0.1	ND	ND	ND	ND	ND	ND	ND
Dibromoacetoneitrile ^e	0.1	ND	ND	ND	ND	ND	ND	ND
Trichloroacetoneitrile ^e	0.1	ND	ND	ND	ND	ND	ND	ND
Bromodichloroacetoneitrile	0.5	ND		ND	ND	ND		
Dibromochloroacetoneitrile	0.5	ND		ND	ND	ND		
Tribromoacetoneitrile	0.90	ND		ND	ND	ND		
<u>Haloacetaldehydes</u>								
Dichloroacetaldehyde	0.22	ND	0.9	1	2	14	14	15
Bromochloroacetaldehyde	0.5	ND	ND	ND	ND	ND	ND	ND
Chloral hydrate ^e	0.1	0.6	0.6	0.6	0.4	0.6	0.4	0.3
Tribromoacetaldehyde	0.1	ND	ND	ND	ND	ND	ND	ND

Table 14 (continued)

09/24/2001	MRL ^a	Plant 7 ^b						
Compound	µg/L	Raw	Settled	Filt Eff	O3 Eff	Plant Eff	DS	SDS
<u>Haloketones</u>								
Chloropropanone	0.1	ND	0.1	0.1	0.4	0.8	0.8	0.8
1,1-Dichloropropanone ^e	0.10	ND	0.3	0.2	0.2	1	1	0.5
1,3-Dichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1,1-Dibromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloropropanone ^e	0.1	ND	ND	ND	ND	ND	ND	ND
1,1,3-Trichloropropanone	0.1	ND	ND	0.4	ND	ND	ND	ND
1-Bromo-1,1-dichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1,1,1-Tribromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1,1,3-Tribromopropanone	0.5	ND	ND	0.6	ND	ND	ND	ND
1,1,3,3-Tetrachloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1,1,1,3-Tetrachloropropanone	0.10	ND	ND	0.4	0.1	ND	ND	ND
1,1,3,3-Tetrabromopropanone	0.5	ND	ND	ND	ND	ND	ND	ND
<u>Halonitromethanes</u>								
Bromonitromethane	0.1	ND	ND	ND	ND	ND	ND	ND
Dichloronitromethane	0.1	ND	ND	ND	ND	0.3	0.2	0.3
Bromochloronitromethane	0.1	ND	ND	ND	ND	ND	ND	ND
Dibromonitromethane	0.10	ND	ND	ND	ND	ND	ND	ND
Chloropicrin ^e	0.1	ND	ND	ND	ND	ND	ND	ND
Bromodichloronitromethane	0.5	ND		ND	ND	1		
Dibromochloronitromethane	0.5	ND		ND	ND	0.8		
Bromopicrin	0.5	ND		ND	ND	ND		
<u>Miscellaneous Compounds</u>								
Methyl ethyl ketone	0.5	ND		ND		1	ND	0.9
Methyl <i>tertiary</i> butyl ether	0.2	ND		ND		ND	ND	ND
Benzyl chloride	0.25	ND	NR	ND	NR	ND	ND	ND
1,1,2,2-Tetrabromo-2-chloroethane	0.5	ND	ND	ND	ND	ND	ND	ND

Table 15. DBP results at plant 8 (9/24/01)

09/24/2001	MRL ^a	Plant 8 ^c						
Compound	µg/L	Raw	Settled	Filt Eff	Tower Eff	Plant Eff	DS	SDS
<u>Halomethanes</u>								
Chloromethane	0.2			ND	ND	ND	ND	ND
Bromomethane	0.2			ND	ND	ND	ND	ND
Bromochloromethane	0.5			ND	ND	ND	ND	ND
Dibromomethane	0.5			ND	ND	ND	ND	ND
Chloroform ^e	0.1	1	16	63	0.5	35	27	26
Bromodichloromethane ^e	0.1	0.2	2	10	0.4	5	5	5
Dibromochloromethane ^e	0.1	ND	0.2	1	0.2	0.9	1	1
Bromoform ^e	0.1	ND	ND	ND	ND	0.1	0.2	0.2
THM4 ^g		1	18	74	1	41	33	32
Dichloriodomethane	0.5	NR	NR	7	ND	3	2	4
Bromochloriodomethane	0.25	NR	NR	ND	ND	ND	0.3	0.3
Dibromiodomethane	0.52	ND	ND	ND	ND	ND	ND	ND
Chlorodiiodomethane	0.1	ND	ND	ND	ND	ND	ND	ND
Bromodiiodomethane	0.5	ND	ND	ND	ND	ND	ND	ND
Iodoform	0.1	ND	ND	ND	ND	ND	ND	ND
Carbon tetrachloride	0.2			ND	ND	ND	ND	ND
Tribromochloromethane	0.5	ND	ND	ND	ND	ND	ND	ND
<u>Haloacetic acids</u>								
Monochloroacetic acid ^e	2		ND	4.1	ND	2.4	ND	2.3
Monobromoacetic acid ^e	1		ND	ND	ND	ND	ND	ND
Dichloroacetic acid ^e	1		7.0	28	1.5	18	19	19
Bromochloroacetic acid ^e	1		ND	3.0	ND	2.5	2.6	3.4
Dibromoacetic acid ^e	1		ND	ND	ND	ND	1.0	1.0
Trichloroacetic acid ^e	1		2.0	7.3	ND	3.2	3.3	3.0
Bromodichloroacetic acid	1		ND	1.6	ND	ND	ND	ND
Dibromochloroacetic acid	1		ND	ND	ND	ND	ND	ND
Tribromoacetic acid	2		ND	ND	ND	ND	ND	ND
HAA5 ^f			9.0	39	1.5	24	23	25
HAA9 ^f			9.0	44	1.5	26	26	29
DXAA ^k			7.0	31	1.5	21	23	23
TXAA ^l			2.0	8.9	ND	3.2	3.3	3.0
<u>Haloacetonitriles</u>								
Chloroacetonitrile	0.1	ND	ND	ND	ND	ND	ND	0.1
Bromoacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND
Dichloroacetonitrile ^e	0.1	ND	ND	2	0.2	0.5	0.8	0.3
Bromochloroacetonitrile ^e	0.1	ND	ND	0.3	0.1	0.4	0.6	0.3
Dibromoacetonitrile ^e	0.1	ND	ND	ND	ND	0.2	0.2	0.1
Trichloroacetonitrile ^e	0.1	ND	ND	ND	ND	ND	ND	ND
Bromodichloroacetonitrile	0.5		ND	ND	ND	ND		
Dibromochloroacetonitrile	0.5		ND	ND	ND	ND		
Tribromoacetonitrile	0.90		ND	ND	ND	ND		
<u>Haloacetaldehydes</u>								
Dichloroacetaldehyde	0.22	0.2	4	2	ND	0.9	2	2
Bromochloroacetaldehyde	0.5	ND	0.6	ND	ND	ND	ND	ND
Chloral hydrate ^e	0.1	0.7	0.9	3	0.2	0.3	0.7	0.3
Tribromoacetaldehyde	0.1	ND	ND	ND	ND	ND	ND	ND

Table 15 (continued)

09/24/2001	MRL ^a	Plant 8 ^c						
Compound	µg/L	Raw	Settled	Filt Eff	Tower Eff	Plant Eff	DS	SDS
<u>Haloketones</u>								
Chloropropanone	0.1	ND	0.1	0.2	0.5	0.1	0.2	0.4
1,1-Dichloropropanone ^e	0.10	ND	ND	0.5	0.1	0.3	0.3	0.2
1,3-Dichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1,1-Dibromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloropropanone ^e	0.1	ND	ND	0.2	ND	0.1	ND	ND
1,1,3-Trichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1-Bromo-1,1-dichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1,1,1-Tribromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1,1,3-Tribromopropanone	0.5	ND	ND	ND	ND	ND	ND	ND
1,1,3,3-Tetrachloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1,1,1,3-Tetrachloropropanone	0.10	ND	0.5	0.2	ND	ND	ND	ND
1,1,3,3-Tetrabromopropanone	0.5	ND	ND	ND	ND	ND	ND	ND
<u>Halonitromethanes</u>								
Bromonitromethane	0.1	ND	ND	ND	ND	ND	ND	ND
Dichloronitromethane	0.1	ND	ND	ND	ND	ND	ND	ND
Bromochloronitromethane	0.1	ND	ND	ND	ND	ND	ND	ND
Dibromonitromethane	0.10	ND	ND	ND	ND	ND	ND	ND
Chloropicrin ^e	0.1	ND	ND	0.2	ND	ND	0.1	0.2
Bromodichloronitromethane	0.5		ND	0.5	ND	0.5		
Dibromochloronitromethane	0.5		ND	ND	ND	0.6		
Bromopicrin	0.5		ND	ND	0.6	0.6		
<u>Miscellaneous Compounds</u>								
Methyl ethyl ketone	0.5			ND	ND	ND	ND	0.9
Methyl <i>tertiary</i> butyl ether	0.2			ND	ND	ND	ND	ND
Benzyl chloride	0.25	NR	NR	ND	ND	ND	ND	ND
1,1,2,2-Tetrabromo-2-chloroethane	0.5	ND	ND	ND	ND	ND	ND	ND

Table 16. Occurrence of other DBPs^a at plant 8 (9/24/01)

Compound	FE	PE	Compound	FE	PE
<u>Halomethanes</u>			<u>Miscellaneous Halogenated DBPs</u>		
Dibromomethane	x	x	Hexachlorocyclopentadiene	x	x
<i>Bromodichloromethane^b</i>	x	x	Bromopentachlorocyclopentadiene	x	x
<i>Dibromochloromethane</i>	x	x	<u>Non-halogenated DBPs</u>		
<i>Bromoform</i>	x	x	<i>Acetone</i>	x	x
<i>Dichloroiodomethane</i>	x	x	<i>Propanal</i>	x	x
<i>Bromochloroiodomethane</i>	x	x	<i>2-Butanone</i>	x	x
<i>Diiodochloromethane</i>	x	x	<i>3-Hexanone</i>	x	x
<u>Haloacids</u>			<i>2-Hexanone</i>	x	x
<i>Bromoacetic acid</i>	x	-	<i>Glyoxal</i>	x	x
<i>Dichloroacetic acid</i>	x	x	<i>Methyl glyoxal</i>	x	x
<i>Bromochloroacetic acid</i>	x	x	<i>Heptanoic acid</i>	-	x
<i>Dibromoacetic acid</i>	x	x	<i>Octanoic acid</i>	-	x
<i>Bromodichloroacetic acid</i>	x	x	<i>Nonanoic acid</i>	-	x
<i>Trichloroacetic acid</i>	x	x	<i>Decanoic acid</i>	-	x
<u>Haloacetonitriles</u>			<i>Undecanoic acid</i>	-	x
Dichloroacetonitrile	x	x	<i>Dodecanoic acid</i>	-	x
Bromochloroacetonitrile	x	x	<i>Tetradecanoic acid</i>	-	x
Dibromoacetonitrile	x	x	<i>Pentadecanoic acid</i>	-	x
<u>Haloaldehydes</u>			<i>Hexadecanoic acid</i>	-	x
Dichloroacetaldehyde	x	x	<i>Heptadecanoic acid</i>	-	x
Dibromoacetaldehyde	-	x	<i>Octadecanoic acid</i>	-	x
Trichloroacetaldehyde	-	x	<i>Butanedioic acid</i>	-	x
2-Bromo-2-methylpropanal	x	x	<i>Pentanedioic acid</i>	-	x
<u>Haloketones</u>			<i>Octanedioic acid</i>	-	x
Chloropropanone	x	x	<i>Nonanedioic acid</i>	-	x
1,1-Dichloropropanone	x	x	<i>Decanedioic acid</i>	-	x
1-Bromo-1-chloropropanone	x	x	<i>Benzene-1,3-dicarboxylic acid</i>	-	x
1,1,3-Trichloropropanone	-	x			
1-Bromo-1,1-dichloropropanone	-	x			
1,1,3,3-Tetrachloropropanone	x	x			
1-Bromo-1,3,3-trichloropropanone	x	x			
<i>1,1-Dibromo-3,3-dichloropropanone</i>	x	x			
<i>1,3-Dibromo-1,3-dichloropropanone</i>	x	x			
<i>1,1,3-Tribromo-3-chloropropanone</i>	x	x			
<i>1,1,3,3-Tetrabromopropanone</i>	x	x			
<u>Halonitromethanes</u>					
Dichloronitromethane	x	x			
<i>Bromochloronitromethane</i>	-	x			

^aDBPs detected by broadscreen gas chromatography/mass spectrometry (GC/MS) technique

^bCompounds listed in italics were confirmed through the analysis of authentic standards; haloacids and non-halogenated carboxylic acids identified as their methyl esters.

Table 17. DBP results at plant 7 (1/14/02)

1/14/2002	MRL ^a	Plant 7 ^b						
Compound	µg/L	Raw	Settled	Filt Eff	O3 Eff	Plant Eff	DS	SDS
<u>Halomethanes</u>								
Chloromethane	0.2	ND ^d		ND		ND	ND	ND
Bromomethane	0.2	ND		ND		ND	ND	ND
Bromochloromethane	0.5	ND		ND		ND	ND	ND
Dibromomethane	0.5	ND		ND		ND	ND	ND
Chloroform ^e	0.2	ND	NR ^f	3	4	6	8	8
Bromodichloromethane ^e	0.2	ND	NR	0.3	0.6	2	1	1
Dibromochloromethane ^e	0.5	ND	ND	0.5	<0.5 ⁿ	<0.5	ND	ND
Bromoform ^e	0.1	ND	ND	ND	ND	ND	ND	ND
THM4 ^g		ND	NR	4	5	8	9	9
Dichloriodomethane	2.5	ND	NR	ND	NR	ND	ND	ND
Bromochloriodomethane	0.5	ND	NR	ND	ND	ND	ND	ND
Dibromiodomethane	0.53	ND	ND	ND	ND	ND	ND	ND
Chlorodiiodomethane	0.1	ND	ND	ND	ND	ND	ND	ND
Bromodiiodomethane	0.52	ND	ND	ND	ND	ND	ND	ND
Iodoform	0.22	ND	ND	ND	ND	ND	ND	ND
Carbon tetrachloride	0.2	ND		ND	ND	ND	0.2	ND
Tribromochloromethane	0.5	ND	ND	ND	ND	ND	ND	ND
<u>Haloacetic acids</u>								
Monochloroacetic acid ^e	2		ND	ND		3.7	4.1	5.4
Monobromoacetic acid ^e	1		ND	ND		ND	ND	ND
Dichloroacetic acid ^e	1		ND	3.9		15	15	22
Bromochloroacetic acid ^e	1		ND	ND		1.6	1.6	2.0
Dibromoacetic acid ^e	1		ND	ND		ND	ND	ND
Trichloroacetic acid ^e	1		ND	ND		1.8	1.7	2.0
Bromodichloroacetic acid	1		ND	ND		ND	ND	ND
Dibromochloroacetic acid	1		ND	ND		ND	ND	ND
Tribromoacetic acid	2		ND	ND		ND	ND	ND
HAA5 ^j			ND	3.9		21	21	29
HAA9 ^j			ND	3.9		22	22	31
DXAA ^k			ND	3.9		17	17	24
TXAA ^l			ND	ND		1.8	1.7	2.0
<u>Haloacetonitriles</u>								
Chloroacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND
Bromoacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND
Dichloroacetonitrile ^e	NA	ND	ND	ND	ND	0.6	NR	NR
Bromochloroacetonitrile ^e	0.5	ND	ND	ND	ND	ND	ND	ND
Dibromoacetonitrile ^e	0.25	ND	ND	ND	ND	ND	ND	ND
Trichloroacetonitrile ^e	0.1	ND	ND	ND	ND	ND	ND	ND
Bromodichloroacetonitrile	NA	ND		ND	ND	ND		
Dibromochloroacetonitrile	NA	ND		ND	ND	ND		
Tribromoacetonitrile	NA	ND		ND	ND	ND		
<u>Haloacetaldehydes</u>								
Dichloroacetaldehyde	0.98	ND	ND	ND	ND	8	9	11
Bromochloroacetaldehyde	0.5	ND	ND	ND	ND	ND	ND	ND
Chloral hydrate ^e	0.1	0.7	0.2	ND	0.1	0.5	0.3	0.7
Tribromoacetaldehyde	0.1	ND	ND	ND	ND	ND	ND	ND

ⁿ<0.5: Concentration less than MRL of 0.5 µg/L

Table 17 (continued)

1/14/2002	MRL ^a	Plant 7 ^b						
Compound	µg/L	Raw	Settled	Filt Eff	O3 Eff	Plant Eff	DS	SDS
<u>Haloketones</u>								
Chloropropanone	0.5	ND	NR	ND	NR	1	1	ND
1,1-Dichloropropanone ^e	NA	ND	ND	ND	ND	1	NR	NR
1,3-Dichloropropanone	0.1	0.2	ND	ND	ND	ND	ND	ND
1,1-Dibromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloropropanone ^e	0.1	ND	ND	ND	ND	0.1	ND	ND
1,1,3-Trichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1-Bromo-1,1-dichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1,1,1-Tribromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1,1,3-Tribromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1,1,3,3-Tetrachloropropanone	0.10	ND	ND	ND	ND	ND	ND	ND
1,1,1,3-Tetrachloropropanone	0.10	ND	ND	ND	ND	ND	ND	ND
1,1,3,3-Tetrabromopropanone	0.5	ND	ND	ND	ND	ND	ND	ND
<u>Halonitromethanes</u>								
Chloronitromethane	0.5	ND		0.6	0.6	0.5	ND	ND
Bromonitromethane	0.1	ND	ND	ND	ND	ND	ND	ND
Dichloronitromethane	NA	ND	NR	0.4	0.5	0.7	NR	NR
Bromochloronitromethane	0.1	ND	ND	ND	ND	ND	ND	ND
Dibromonitromethane	0.10	ND	ND	ND	ND	ND	ND	ND
Chloropicrin ^e	0.1	ND	ND	ND	0.1	0.4	0.2	0.4
Bromodichloronitromethane	NA	ND		ND	ND	3		
Dibromochloronitromethane	NA	ND		ND	ND	ND		
Bromopicrin	NA	ND		ND	ND	ND		
<u>Miscellaneous Compounds</u>								
Methyl ethyl ketone	0.5	ND		ND		0.6	0.8	0.9
Methyl <i>tertiary</i> butyl ether	0.2	ND		ND		ND	ND	ND
Benzyl chloride	0.2	ND	ND	ND	ND	ND	ND	ND
1,1,2,2-Tetrabromo-2-chloroethane	0.5	ND	ND	ND	ND	ND	ND	ND

Table 18. DBP results at plant 8 (1/16/02)

1/16/2002	MRL ^a	Plant 8 ^c						
Compound	µg/L	Raw	Settled	Filt Eff	Tower Eff	Plant Eff	DS	SDS
Halomethanes								
Chloromethane	0.2			ND ^d	ND	ND	ND	ND
Bromomethane	0.2			ND	ND	ND	ND	ND
Bromochloromethane	0.5			ND	ND	ND	ND	ND
Dibromomethane	0.5			ND	ND	ND	ND	ND
Chloroform ^e	0.2	ND	14	59	0.3	25	32	28
Bromodichloromethane ^e	0.2	ND	2	6	0.9	3	3	3
Dibromochloromethane ^e	0.5	ND	0.8	0.9	0.8	0.7	0.7	0.5
Bromoform ^e	0.1	ND	ND	ND	ND	ND	ND	ND
THM4 ^g		ND	17	66	2	29	36	32
Dichloriodomethane	2.5	NR ^f	NR	3	ND	<2.5 ^o	<2.5	ND
Bromochloriodomethane	0.5	NR	ND	ND	ND	ND	ND	ND
Dibromiodomethane	0.53	ND	ND	ND	ND	ND	ND	ND
Chlorodiodomethane	0.1	ND	ND	ND	ND	ND	ND	ND
Bromodiodomethane	0.52	ND	ND	ND	ND	ND	ND	ND
Iodoform	0.22	ND	ND	ND	ND	ND	ND	ND
Carbon tetrachloride	0.2		0.2	0.3	0.6	ND	ND	ND
Tribromochloromethane	0.5	ND	ND	ND	ND	ND	ND	ND
Haloacetic acids								
Monochloroacetic acid ^e	2		ND	2.7	3.4	ND	ND	2.7
Monobromoacetic acid ^e	1		ND	ND	ND	ND	ND	ND
Dichloroacetic acid ^e	1		9.9	28	1.2	17	16	16
Bromochloroacetic acid ^e	1		ND	2.6	ND	1.5	1.4	1.9
Dibromoacetic acid ^e	1		ND	ND	ND	ND	ND	ND
Trichloroacetic acid ^e	1		2.1	6.8	ND	2.6	2.4	2.4
Bromodichloroacetic acid	1		ND	1.3	ND	ND	ND	2.5
Dibromochloroacetic acid	1		ND	ND	ND	ND	ND	ND
Tribromoacetic acid	2		ND	ND	ND	ND	ND	ND
HAA5 ^j			12	38	4.6	20	18	21
HAA9 ^j			12	41	4.6	21	20	26
DXAA ^k			10	31	1.2	19	17	18
TXAA ^l			2.1	8.1	ND	2.6	2.4	4.9
Haloacetonitriles								
Chloroacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND
Bromoacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND
Dichloroacetonitrile ^e	NA	ND	ND	0.9	ND	ND	NR	NR
Bromochloroacetonitrile ^e	0.5	ND	ND	<0.5 ⁿ	ND	<0.5	<0.5	<0.5
Dibromoacetonitrile ^e	0.25	ND	ND	ND	ND	ND	ND	ND
Trichloroacetonitrile ^e	0.1	ND	ND	ND	ND	ND	ND	ND
Bromodichloroacetonitrile	NA		ND	ND	ND	ND		
Dibromochloroacetonitrile	NA		ND	ND	ND	ND		
Tribromoacetonitrile	NA		ND	ND	ND	ND		
Haloacetaldehydes								
Dichloroacetaldehyde	0.98	1	ND	1	ND	ND	ND	1
Bromochloroacetaldehyde	0.5	ND	ND	ND	ND	ND	ND	ND
Chloral hydrate ^e	0.1	0.3	0.7	2	0.3	0.2	0.2	0.1
Tribromoacetaldehyde	0.1	ND	ND	ND	ND	ND	ND	ND

^o<2.5: Concentration less than MRL of 2.5 µg/L

Table 18 (continued)

1/16/2002	MRL ^a	Plant 8 ^c						
Compound	µg/L	Raw	Settled	Filt Eff	Tower Eff	Plant Eff	DS	SDS
<u>Haloketones</u>								
Chloropropanone	0.5	ND	NR	ND	ND	ND	ND	ND
1,1-Dichloropropanone ^e	NA	ND	ND	0.9	ND	ND	NR	NR
1,3-Dichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1,1-Dibromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloropropanone ^e	0.1	ND	ND	0.5	ND	ND	ND	ND
1,1,3-Trichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1-Bromo-1,1-dichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1,1,1-Tribromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1,1,3-Tribromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1,1,3,3-Tetrachloropropanone	0.10	ND	ND	ND	ND	ND	ND	ND
1,1,1,3-Tetrachloropropanone	0.10	ND	ND	ND	ND	ND	ND	ND
1,1,3,3-Tetrabromopropanone	0.5	ND	ND	ND	ND	ND	ND	ND
<u>Halonitromethanes</u>								
Chloronitromethane	0.5		2	<0.5	<0.5	ND	ND	ND
Bromonitromethane	0.1	ND	ND	ND	ND	ND	ND	ND
Dichloronitromethane	NA	ND	0.4	0.5	ND	ND	NR	NR
Bromochloronitromethane	0.1	ND	ND	ND	ND	ND	ND	ND
Dibromonitromethane	0.10	ND	ND	ND	ND	ND	ND	ND
Chloropicrin ^e	0.1	ND	ND	0.6	ND	0.4	0.3	0.3
Bromodichloronitromethane	NA		ND	1	1	0.9		
Dibromochloronitromethane	NA		ND	ND	ND	ND		
Bromopicrin	NA		ND	ND	1	ND		
<u>Miscellaneous Compounds</u>								
Methyl ethyl ketone	0.5			ND	1	ND	<0.5	ND
Methyl <i>tertiary</i> butyl ether	0.2			ND	0.3	ND	ND	ND
Benzyl chloride	0.2	ND	ND	ND	ND	ND	ND	ND
1,1,2,2-Tetrabromo-2-chloroethane	0.5	ND	ND	ND	ND	ND	ND	ND

Table 19. Additional target DBP results (µg/L) at plants 7 and 8 (1/14-16/02)

1/14-16/02	Plant 7 ^a						Plant 8 ^a					
Compound	Raw	FE	OE	PE	DS	SDS	Raw	FE	STE	PE	DS	SDS
Monochloroacetaldehyde	0	0	3.1	1.9	1.5	2.2	0	0.2	0		0	0
Dichloroacetaldehyde	0	1.6	7.5	12.2	9.2	13.1	0	1.3	0		0.9	1.0
Bromochloroacetaldehyde	0	0.1	0.2	0.6	0.4	0.6	0	0.3	0		0.1	0.1
3,3-Dichloropropenoic acid	0	0	0	0	0	0.6	0	0.1	0	0	0	0
Bromochloromethylacetate	0	0	0	0	0	0	0	0	0	0	0	0
Monochloroacetamide	0	0	0	0	0	0	0			0	0	0
Monobromoacetamide	0	0	0	0	0	0	0			0	0	0
Dichloroacetamide	0	0.1	0.2	1.8	2.5	3.0	0			1.5	1.4	1.2
Dibromoacetamide	0	0	0	0.2	0.4	0.5	0			0.3	0.2	0.2
Trichloroacetamide	0	0	0	0.1	0.2	0.3	0			0.1	0.6	0.5
TOX (µg/L as Cl ⁻)	0	94.9	94.2	200	154	212	0	486	40.4	179	161	133
TOBr (µg/L as Br ⁻)		17.0	12.0	36.5	23.2	42.1	0	137	24.0	80.9	64.0	68.0
TOCl (µg/L as Cl ⁻)		83.5	85.0	206	121	185	0	450	29.7	203	189	190
Cyanoformaldehyde	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
5-Keto-1-hexanal	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
6-Hydroxy-2-hexanone	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Dimethylglyoxal	<0.1	<0.1	2.4	2.8	1.9	2.5	<0.1	0.8	<0.1	<0.1	<0.1	<0.1
<i>trans</i> -2-Hexenal	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

Table 20. Halogenated furanone results (µg/L) at plant 7 (1/14/02)

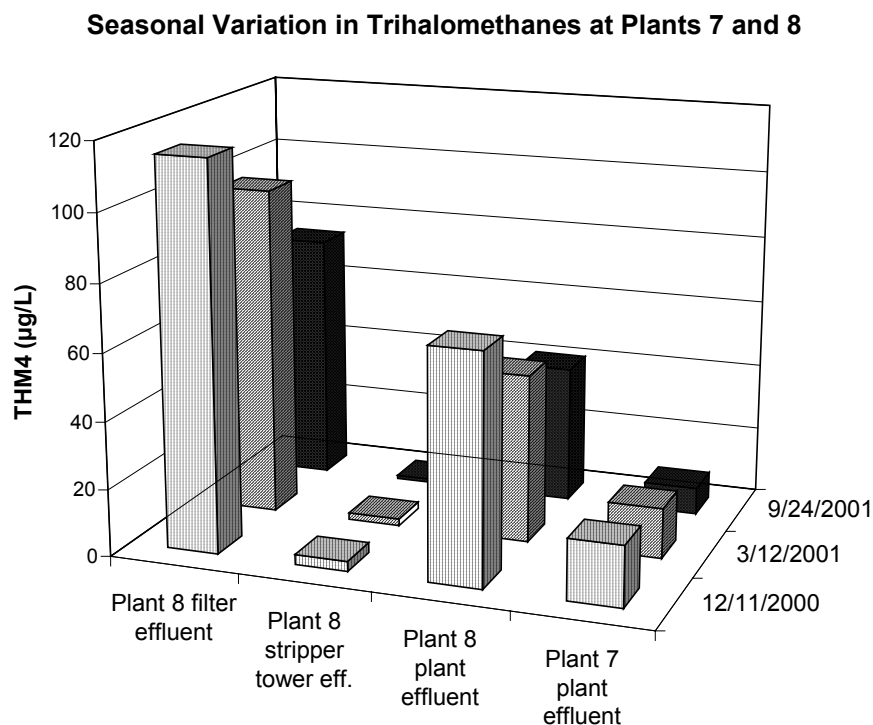
Compound	Raw	FE	OE	PE	DS	SDS
BMX-1	<0.02	<0.02	<0.02	0.03	<0.02	0.02
BEMX-1	<0.02	<0.02	0.03	<0.02	<0.02	<0.02
BMX-2	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
BEMX-2	<0.02	<0.02	<0.02	0.06	0.06	0.03
BMX-3	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
BEMX-3	0.10	0.10	0.15	0.28	0.18	0.18
MX	<0.02	<0.02	<0.02	0.17	<0.02	0.04
EMX	<0.02	<0.02	<0.02	0.05	<0.02	<0.02
ZMX	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02 (0.013)
Ox-MX	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Mucochloric acid (<i>ring</i>)	<0.02	<0.02	<0.02 (0.015)	0.02	0.05	0.02
Mucochloric acid (<i>open</i>)	<0.02	0.03	0.08	0.20	0.21	0.22

Table 21. Halogenated furanone results (µg/L) at plant 8 (1/16/02)

Compound	Raw	FE	PE	DS	SDS
BMX-1	<0.02	<0.02	0.11	0.03	0.05
BEMX-1	0.08	<0.02 (0.011)	0.72	<0.02	<0.02
BMX-2	<0.02	<0.02	<0.02 (0.014)	0.03	0.02
BEMX-2	<0.02	0.12	0.81	0.11	0.10
BMX-3	<0.02	<0.02	0.04	<0.02	<0.02
BEMX-3	<0.02	0.43	0.41	0.37	1.28
MX	<0.02	<0.02 (0.015)	0.10	0.12	0.10
EMX	<0.02	<0.02	<0.02	<0.02	<0.02
ZMX	<0.02	0.09	<0.02	<0.02	<0.02
Ox-MX	<0.02	<0.02	<0.02	<0.02	<0.02
Mucochloric acid (<i>ring</i>)	<0.02	0.02	0.02	0.02	0.02
Mucochloric acid (<i>open</i>)	<0.02	0.30	0.16	0.17	0.18

Halomethanes. Pre-chloramination at plant 7 resulted in the formation of 3-18 $\mu\text{g/L}$ of the four regulated trihalomethanes (THM4) by the filter effluent sampling point. Post-ozonation did not change the concentration of the THMs. Post-chlorination at plant 7 resulted in 7-18 $\mu\text{g/L}$ of THM4. Pre-chlorination and intermediate chloramination in the lime softening portion of plant 8 resulted in the formation of 66-115 $\mu\text{g/L}$ of THM4, whereas only 1-3 $\mu\text{g/L}$ was produced in the membrane softening portion of the plant. The combined treated waters at plant 8 after final chloramination contained 29-68 $\mu\text{g/L}$ of THM4. Figure 4 shows the seasonal variation in THM4 at plant 7 and plant 8 in 2000-2001. THM formation did not vary significantly from season to season.

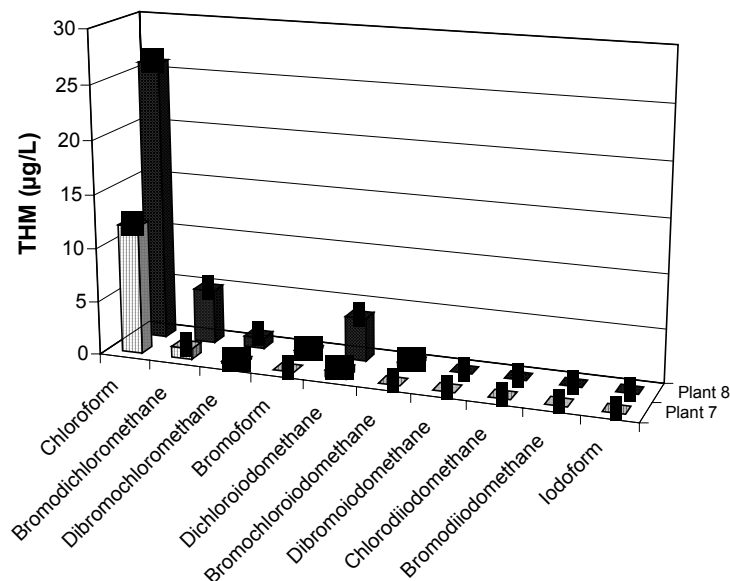
Figure 4



Even though the source groundwaters contained moderate to high levels of bromide (0.12 to 0.33 mg/L), chloroform was the dominant THM (e.g., 91 and 81 % of THM4 in SDS testing in September 2001 at plant 7 and plant 8, respectively) (Figure 5). In other DBP research, it has been shown that bromine speciation is effected by the bromide-to-TOC ratio and the chlorine-to-bromide ratio (Symons et al., 1993). In these samples, both the TOC (11-13 mg/L in raw water) and chlorine dosages (5-13 mg/L at plant 7 influent; 6-8 mg/L at influent to lime softening portion of plant 8) were relatively high. As a result, chlorine was able to effectively compete with bromine in forming halogenated DBPs. In addition, low levels of some of the iodinated THMs were detected (Figure 5; Tables 10, 16, and 18). Because the concentration of bromide was higher at plant 8, this resulted in somewhat more bromine incorporation in the THMs, including the formation of a bromine-containing iodinated THM (Figure 5).

Figure 5

Effect of Bromide and Treatment/Disinfection Process on Trihalomethane Formation and Speciation in Simulated Distribution System Testing (September 24, 2001): Plant 7 Br⁻ = 0.14 mg/L, Plant 8 Br⁻ = 0.25 mg/L



Haloacids. Chloramination and ozonation at plant 7 resulted in the formation of 21-30 µg/L of the five regulated haloacetic acids (HAA5). Pre-chlorination and intermediate chloramination in the lime softening portion of plant 8 resulted in the formation of 38-53 µg/L of HAA5, whereas only 2-5 µg/L were produced in the membrane softening portion of the plant. The combined treated waters at plant 8 after final chloramination contained 17-28 µg/L of HAA5.

In addition, all nine HAAs (HAA9) were measured, which includes all of the brominated HAA species. However, HAA9 values were not significantly higher than the levels of HAA5. This reflects the relatively low bromine substitution that occurred in these waters. Figure 6 shows the seasonal variation in HAA9 at plant 7 and plant 8 in 2000-2001. HAA formation did not vary significantly from season to season.

At both plants, the sum of the dihalogenated HAAs (DXAAs) was much higher than the sum of the trihalogenated HAAs (TXAAs) (Figure 7). In other DBP research, chloramination has been shown to control TXAA formation much better than DXAA formation (Krasner et al., 1996). In addition, ozonation has been shown to be able to destroy trichloroacetic acid (TCAA) precursors better than dichloroacetic acid (DCAA) precursors (Reckhow and Singer, 1984). Furthermore, other research has shown that THM formation—in the presence of free chlorine—was higher with increasing pH (Stevens et al., 1989). In this same research, pH (in the range of 5 to 9.4) had no significant effect on DCAA formation, whereas TCAA formation was lower at pH 9.4 than at the lower pH levels (Stevens et al., 1989). Because chlorine (and chloramines) was applied to lime-softened water at plants 7 and 8, pH was a factor in determining which DBPs

Figure 6

Seasonal Variation in Haloacetic Acids at Plants 7 and 8

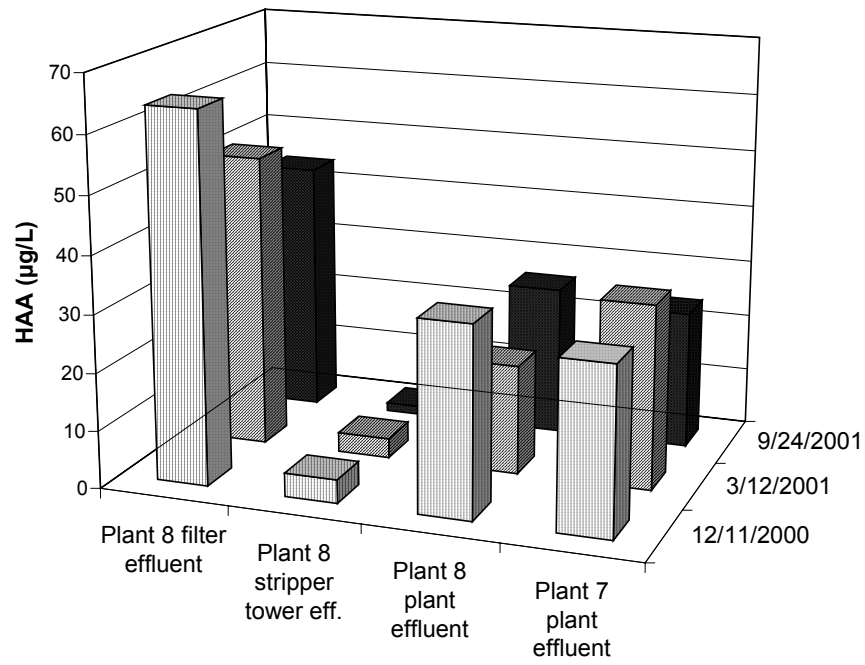
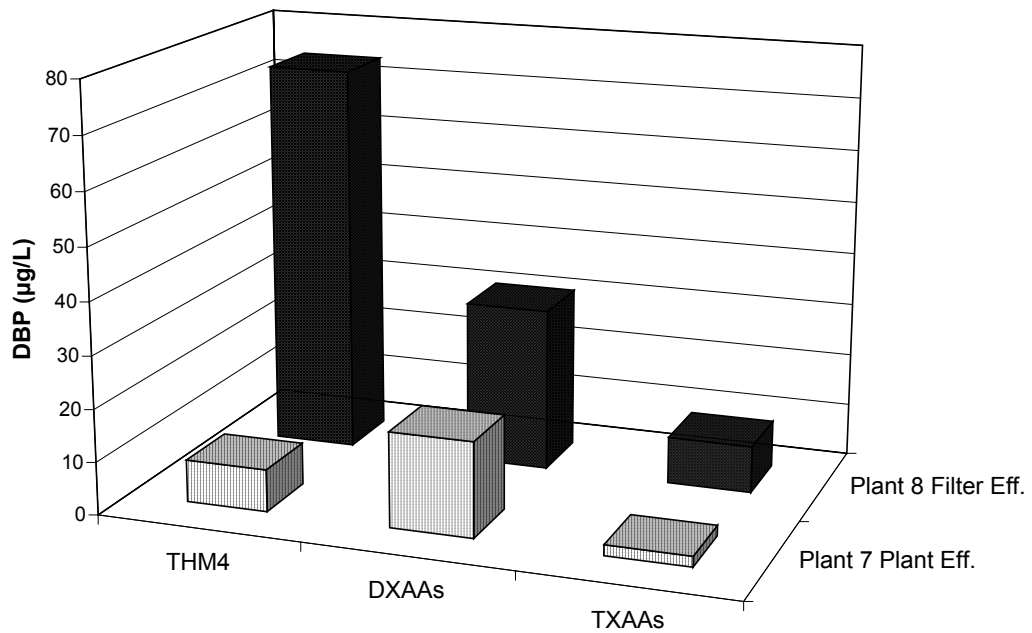


Figure 7

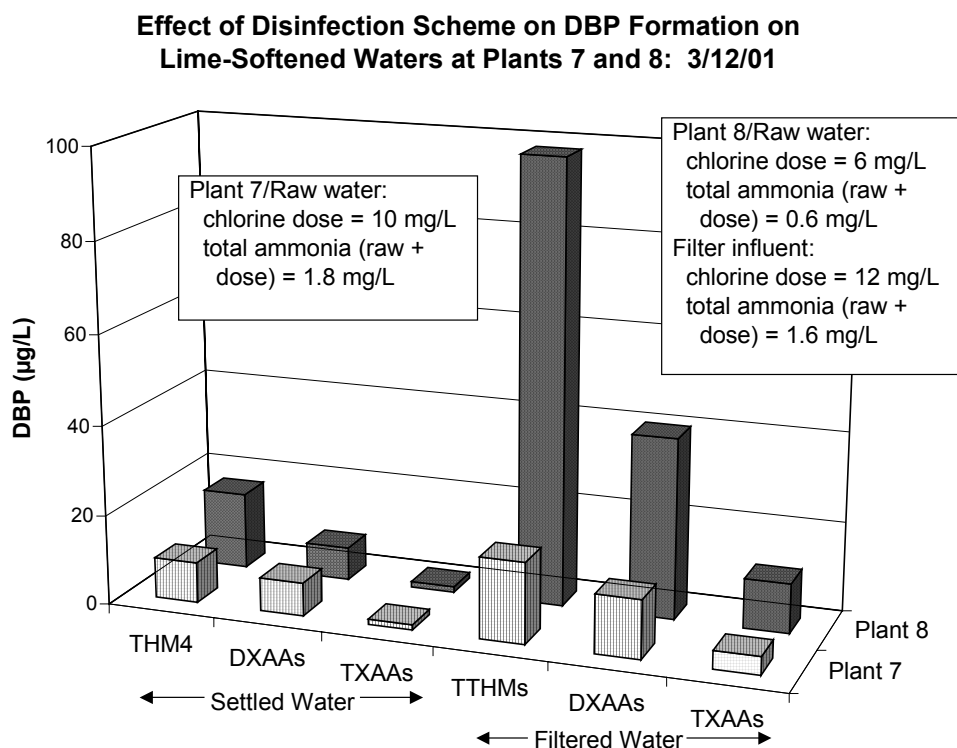
Effect of Treatment/Disinfection Process on Trihalomethane and Haloacetic Acid Formation at Plants 7 and 8 (September 24, 2001)



formed. Because DXAA formation was higher than THM4 formation at plant 7 in September 2001, the use of pre-chloramination was probably the major determinant of the relative proportion of these DBPs during that sampling date. Because THM4 formation was higher than DXAA formation in the softened water at plant 8, the effect of pH was probably the major determinant of the relative proportion of these DBPs.

For example, Figure 8 shows the effect of the disinfection scheme on DBP formation in lime-softened waters at plants 7 and 8 for March 12, 2001. At plant 7, chlorine (10 mg/L) and ammonia (1.1 mg/L) were added to the raw water that contained 0.69 mg/L of ammonia to begin with. At plant 8, on the lime-softening train, chlorine (6.0 mg/L) was added to the raw water. Although ammonia was not added at plant 8, the raw water contained 0.62 mg/L of ammonia. Therefore, both plants were operating with chloramines, which helped minimized DBP formation in this high-TOC groundwater. At plant 8, in the lime-softening portion of the plant, additional chlorine (12 mg/L) and ammonia (1.0 mg/L) were added to the softened water. Although chloramines were still present, it is possible that the “effective” chlorine-to-nitrogen ratio was much higher than in the raw water. At higher chlorine-to-nitrogen ratios, THM formation is more likely to occur (Diehl et al., 2000), as evidenced by the relatively high level of THMs (98 µg/L) in the filter influent sample at plant 8.

Figure 8



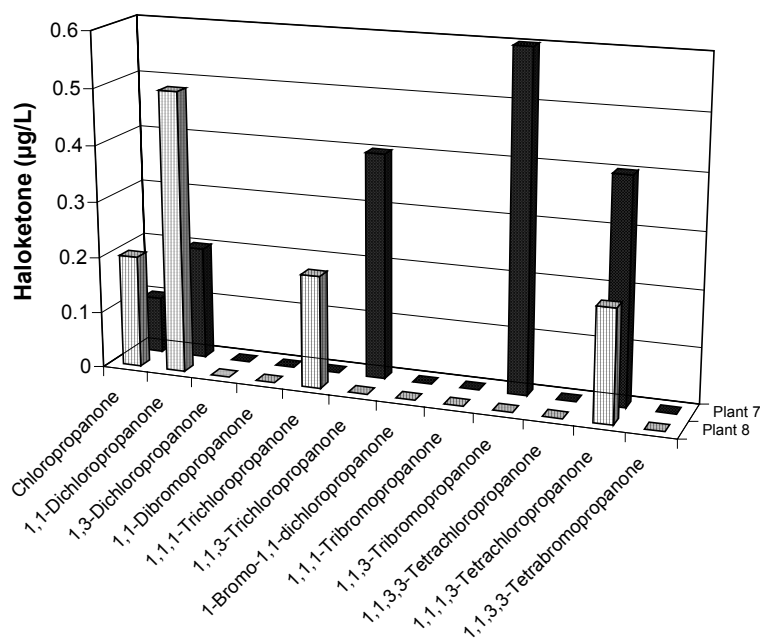
Haloacetonitriles. In other DBP research, haloacetonitriles (HANs) have been found to be produced at approximately one-tenth the level of the THMs (Oliver, 1983). HANs were only observed at plant 8 in the filter effluent sample in December 2000 and in selected samples at both plants in January 2002. HANs can undergo base-catalyzed hydrolysis (Croué and

Reckhow, 1989). Because of the high pH of the treated waters at these two plants, most of the HANs formed were degraded. None of the target HANs—that were not included in the Information Collection Rule (ICR)—were detected in these high-pH samples, except for chloroacetonitrile in the SDS sample at plant 8 in September 2001.

Haloketones. One of the haloketones (HKs) from the ICR—1,1-dichloropropanone (1,1-DCP)—was detected at both plant 7 and plant 8, whereas the other ICR HK (1,1,1-trichloropropanone) was detected in selected samples at plant 8 and in January 2002 at one sample location at plant 7. The latter HK also can undergo base-catalyzed hydrolysis at high pH (Croué and Reckhow, 1989). In addition, some of the other target HKs were detected in selected samples (Figure 9).

Figure 9

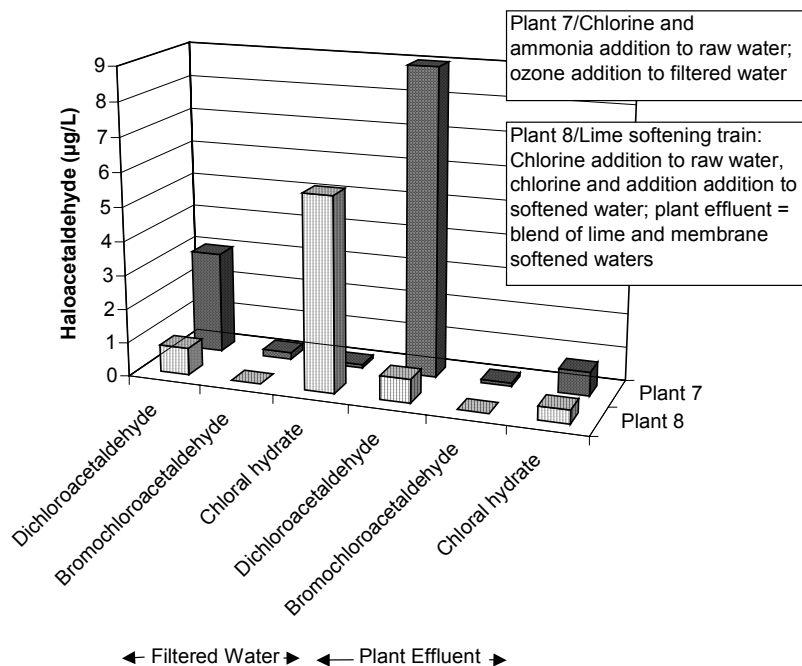
**Formation of Haloketones at Filter Effluents at Plants 7 and 8
(September 24, 2001)**



In addition to the target HKs, other HKs were detected in selected samples by the broadscreen GC/MS methods (Tables 10 and 16). A number of these HKs were analogous to the di- and tetrahalogenated HKs analyzed by MWDSC, except that these were mixed bromochloro species. For example, in December 2000, when the raw-water bromide was at 0.12 mg/L, MWDSC detected chloropropanone; 1,1-DCP; and 1,1,3,3-tetrabromopropanone (1,1,3,3-TeBP) after chloramination and ozonation at plant 7. Broadscreen GC/MS analysis of this same water also detected the bromochloro analogue of 1,1-DCP and four bromochloro analogues of 1,1,3,3-TeBP. Another HK that was detected at plant 7 by the broadscreen GC/MS methods was pentachloropropanone (PCP). MWDSC analysts had attempted to include PCP in its target compound list, but PCP degraded immediately and completely in water under all conditions evaluated (Gonzalez et al., 2000).

Figure 10

Effect of Disinfection/Treatment Scheme and pH (9-10) on Haloacetaldehyde Formation and Stability at Plants 7 and 8: 3/12/01



Haloaldehydes. Chloral hydrate (trichloroacetaldehyde) (an ICR DBP) was detected (2-13 µg/L) in the filter effluent sample at plant 8 (Figure 10). Chloral hydrate also undergoes base-catalyzed hydrolysis (Stevens et al., 1989) (it is converted to chloroform). Thus, its low concentration (0.2-2 µg/L) in the combined treated waters at plant 8 was a result of degradation, not only because of dilution with membrane-treated water. In addition, a low level (≤ 3 µg/L) of dichloroacetaldehyde (a target DBP) was found at plant 8.

In contrast, at plant 7, very little chloral hydrate was detected (<1 µg/L), whereas a high amount of dichloroacetaldehyde (8-14 µg/L) was detected in the finished water (Figure 10). In other DBP research, acetaldehyde (an ozone by-product) was found to react with chlorine to form chloroacetaldehyde, which in the presence of free chlorine rapidly reacted to form chloral hydrate (McKnight and Reckhow, 1992). At plant 7, chlorine (in the presence of ammonia) may have reacted with acetaldehyde formed by the ozonation process to produce dichloroacetaldehyde.

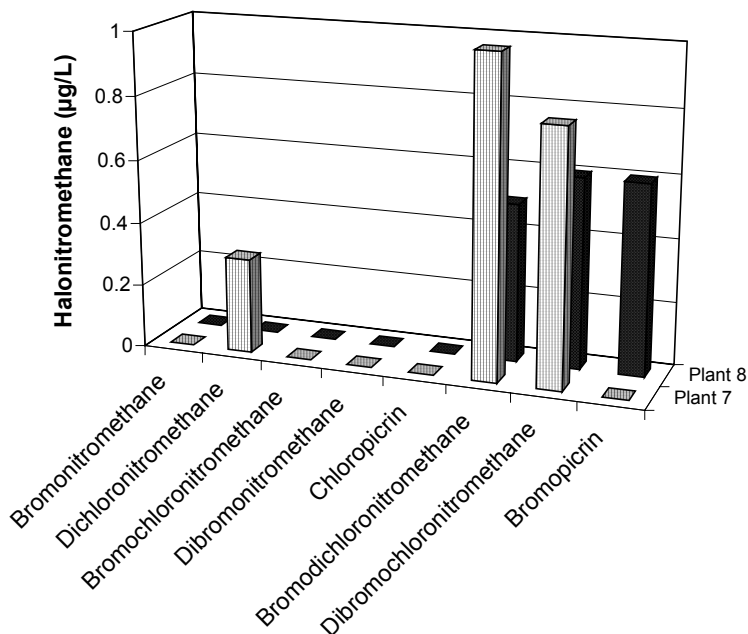
In addition, bromochloroacetaldehyde—a brominated analogue of dichloroacetaldehyde—was detected at sub-µg/L levels at two locations at plant 7 in March 2001. The results for chloral hydrate in December 2000 represented the sum of the concentrations of chloral hydrate and bromochloroacetaldehyde, since these two DBPs co-eluted in the original GC method (Krasner et al., 2001). However, based on the March 2001 results, bromochloroacetaldehyde probably did not contribute that much to the December 2000 chloral hydrate results.

In addition to the target haloaldehydes, two other haloaldehydes were detected in selected samples by the broadscreen GC/MS methods (Tables 10 and 16). Dibromoacetaldehyde, the fully bromine-substituted analogue of dichloro- and bromochloroacetaldehyde, was detected at both plants. Another brominated aldehyde (2-bromo-2-methylpropanal) also was detected at both plants.

Halonitromethanes. Sub- $\mu\text{g/L}$ levels of chloropicrin (trichloronitromethane) (an ICR DBP) were detected at selected sites at plant 8 and in January 2002 at plant 7. In addition, some of the target halonitromethanes were detected at both plant 7 and plant 8 (Figure 11; Tables 10, 16, 17, and 18).

Figure 11

**Formation of Halonitromethanes in Plant Effluents at Plants 7 and 8
(September 24, 2001)**

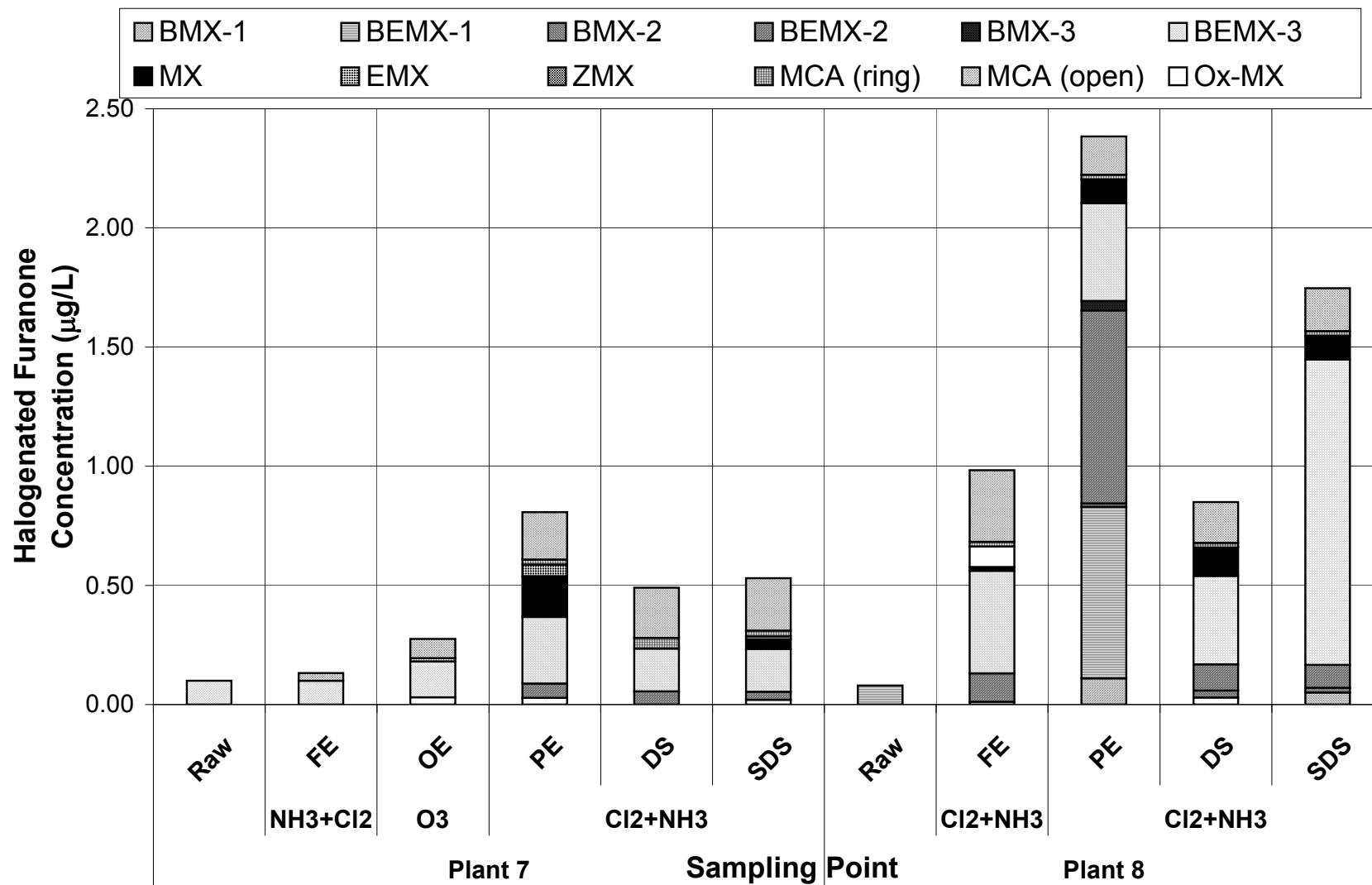


Halogenated Furanones. Tables 20 and 21 show results for halogenated furanones in the January 2002 sampling for plant 7 and plant 8. Data are included for 3-chloro-4-(dichloromethyl)-5-hydroxy-2[5H]-furanone, otherwise known as MX; (E)-2-chloro-3-(dichloromethyl)-4-oxobutenoic acid, otherwise known as EMX; (Z)-2-chloro-3-(dichloromethyl)-4-oxobutenoic acid (ZMX); the oxidized form of MX (Ox-MX); brominated forms of MX and EMX (BMXs and BEMXs); and mucochloric acid (MCA), which can be found as a closed *ring* or in an *open* form. Results are displayed graphically in Figure 12.

At plant 7 (1/14/02), pre-chloramination and post-ozonation controlled (in part) the formation of MX and MX-analogues in a high-TOC (12.6 mg/L) groundwater, as compared

Figure 12

Plants 7 and 8 (1/14-16/02)



to plant 8 (1/16/02) (TOC = 11.3 mg/L) that used lime softening with pre-chlorination in one portion of the plant and membranes in the other portion of the plant to control DBP formation and remove TOC. Likewise, pre-chlorination in the lime softening portion of plant 8 produced more THMs and HAAs than chloramination/ozonation at plant 7 (Figure 7-8). These are the results of only one sample event. Additional measurements of membrane-treated water should be conducted in the future to determine whether these results are repeatable. However, the significant brominated MX-analogue production in plant 8 is consistent with the high-bromide, source-water quality (0.27 mg/L in the raw water and 0.1 mg/L in the membrane effluent).

Volatile Organic Compounds (VOCs). In December 2000, carbon tetrachloride was detected in one sample (distribution system of plant 7) just above its MRL (0.06 µg/L). In March 2001, this compound was found in all of the samples (0.2-0.7 µg/L) except for the raw waters and the effluent of the stripping towers (i.e., membrane-softened water). In September 2001, it was not detected in any of the samples with an MRL of 0.2 µg/L. In January 2002, carbon tetrachloride was detected in one sample (distribution system) of plant 7 at the revised MRL (0.2 µg/L) and in several samples at plant 8 (0.2-0.6 µg/L). Carbon tetrachloride is a VOC and a possible DBP. Carbon tetrachloride has been detected by some utilities in gaseous chlorine cylinders (EE&T, 2000). Incidents of carbon tetrachloride contamination have been traced to either imperfections in the manufacturing process or improper cleaning procedures. Carbon tetrachloride is used to clean out cylinders before filling with chlorine. If carbon tetrachloride is not allowed sufficient time to evaporate, it can contaminate the chlorine.

In September 2001, methyl ethyl ketone (MEK) was detected in selected samples at 0.9-1 µg/L. In January 2002, MEK was detected after ozonation at plant 7 (0.6-0.9 µg/L) and in two samples at plant 8 (<0.5-1 µg/L). MEK is a VOC and a possible DBP. Also in January 2002, methyl *tertiary* butyl ether (MTBE) was detected (0.3 µg/L) in one sample (stripper tower effluent) of plant 8 just above its MRL (0.2 µg/L). MTBE is a VOC, not a DBP.

Other Halogenated DBPs. A few additional, miscellaneous halogenated DBPs were also detected. UNC methods detected dichloroacetamide at 1.8 and 2.1 µg/L in finished waters from plant 7 and plant 8, respectively, in March 2001 (Table 13). In addition, the concentration of dichloroacetamide increased in SDS testing. In samples collected in January 2002, dichloroacetamide, dibromoacetamide, and trichloroacetamide were found in finished waters from both treatment plants at levels for individual species ranging from 0.1 to 3.0 µg/L (Table 19). The concentrations of these latter compounds either increased or remained steady in the distribution system. Broadscreen GC/MS analyses revealed the presence of hexachlorocyclopentadiene and bromopentachlorocyclopentadiene in finished water from plant 7 in December 2000 (Table 10) and plant 8 in September 2001 (Table 16). These compounds were not observed in the corresponding raw, untreated water.

Non-Halogenated DBPs. A few non-halogenated DBPs were also detected in finished waters from plants 7 and 8. Dimethylglyoxal was identified at 3.5 µg/L in finished waters from plant 7 in March 2001 (Table 13) and in finished waters at 2.8 µg/L from plant 7 in January 2002 (Table 19). Broadscreen GC/MS analysis also revealed the presence of formaldehyde, acetone, glyoxal, and methyl glyoxal in plant 7 finished waters in December 2002, and acetone, propanal, 2-butanone, 3-hexanone, 2-hexanone, glyoxal, and methyl glyoxal in finished waters from plant

8 in September 2001 (Table 16). Several non-halogenated carboxylic acids were also observed in the finished waters at significantly higher levels than found in the raw, untreated water (Table 16).

Other DBP Formation and Stability Issues. Figures 13-14 show the effect of seasonal variations on DBP formation at plant 7 (plant effluent) and at plant 8 (filter effluent). Essentially, there did not appear to be any significant seasonal variations in water quality, operations or DBP formation at either of these two treatment plants.

Figure 13

**Effect of Seasonal Variations on DBP Formation at Plant 7:
Plant Effluent**

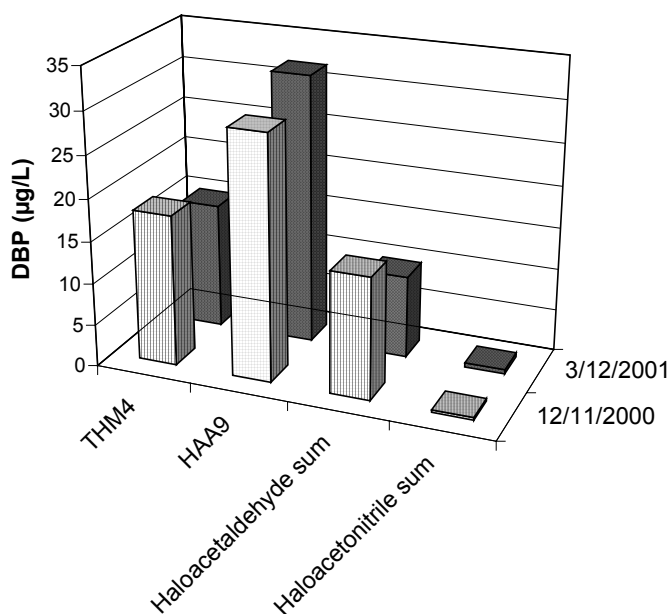
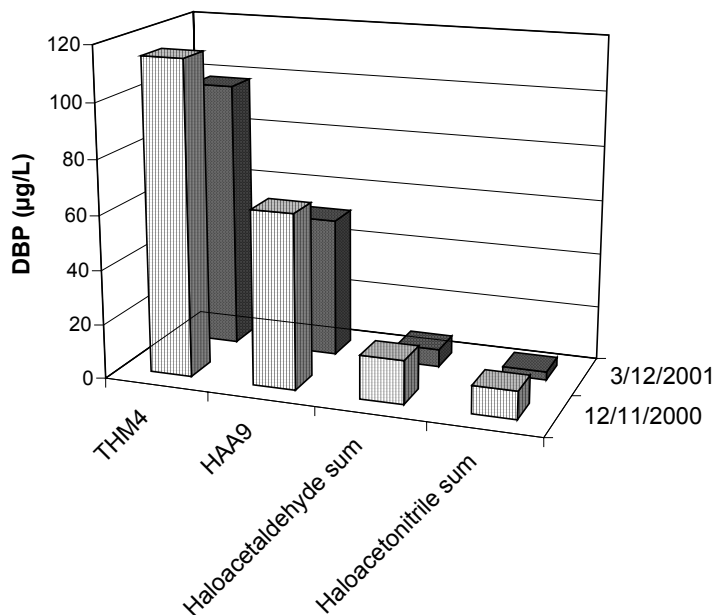


Figure 14

**Effect of Seasonal Variations on DBP Formation at Plant 8:
Filter Effluent**



At plant 7, HAA formation (the sum of all nine species) was greater than THM formation (on a weight basis). The haloacetaldehydes were the third largest fraction (by weight) of halogenated DBPs. At plant 7, most of the haloacetaldehyde formation was due to dichloroacetaldehyde (a target DBP) and not due to chloral hydrate (an ICR DBP). HAN formation was quite small.

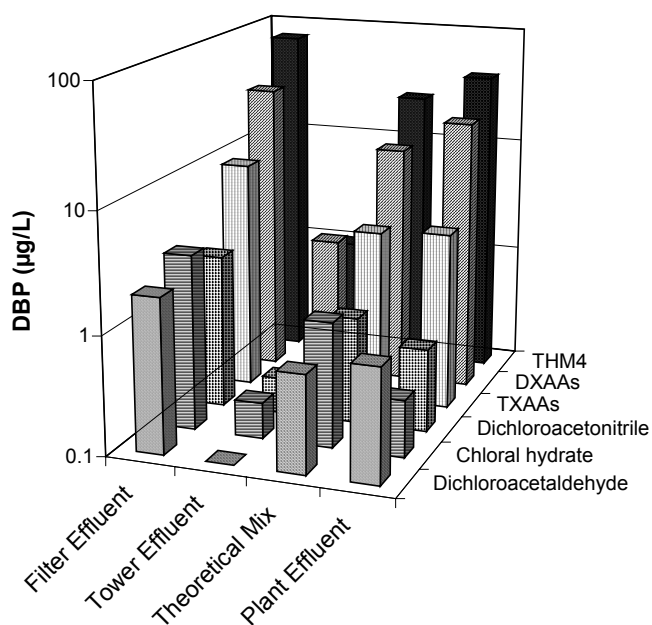
Alternatively, at plant 8, THM formation was greater than HAA formation. The haloacetaldehydes and HANs were the third and fourth largest fractions of halogenated DBPs. The formation of the latter two fractions was higher in December 2000 than in March 2001. During the December 2000 sampling, the pH of the settled water and filter effluent were 9.7 and 9.2, respectively, whereas during the March 2001 sampling, the pH of the settled water and filter effluent were 10.4 and 10.0, respectively. Because chloral hydrate and dichloroacetonitrile (the major components of the latter two fractions at plant 8, respectively) both undergo base-catalyzed hydrolysis, their formation may have been lower in March 2001 because of the somewhat higher pH.

Figure 15 shows the effect of blending lime-softened water (filter effluent) with membrane-softened water (effluent of stripper towers) and base-catalyzed hydrolysis on DBP concentrations in the plant effluent of plant 8 on September 24, 2001. The flows of the lime-softening and membrane-softening portions of the plant were 3.3 and 6.8 mgd, respectively. For the TXAAs, 8.9 µg/L was detected in the lime-softened water, whereas none was detected in the membrane-softened water. Based on blending, using the flows of each portion of the treatment plant, one would expect the TXAAs to be diluted down to 2.9 µg/L. In the actual plant effluent, there was 3.2 µg/L of TXAAs. In contrast, the theoretical levels of dichloroacetonitrile

(0.8 µg/L) and of chloral hydrate (1.1 µg/L) were greater than the measured values (i.e., 0.5 and 0.3 µg/L, respectively). As discussed previously, the lower measured values—especially for chloral hydrate—were due to base-catalyzed hydrolysis. On the other hand, the theoretical levels of DXAAs (11 µg/L) and of THM4 (25 µg/L) were significantly less than the measured values (i.e., 21 and 41 µg/L, respectively). These latter DBPs continued to form downstream of blending (and after additional chlorine addition). In addition, when chloral hydrate is hydrolyzed, chloroform (one of the THMs) is formed. Thus, some of the formation may also be due to the breakdown of other unstable DBPs (at least unstable at pH 9). Finally, dichloroacetaldehyde was relatively conservative (theoretical and measured values of 0.7 and 0.9 µg/L, respectively). Therefore, it did not undergo base-catalyzed hydrolysis as the chloral hydrate (trichloroacetaldehyde) did.

Figure 15

Effect of Blending and pH on Formation and Stability of DBPs at Plant 8 (September 24, 2001)



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